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FURTHER CHARACTERIZATION OF IRAS DOPED SILICON DETECTORS

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TABLE OF CONTENTS

FURTHER CHARACTERIZATION OF IRAS DOPED-SILICON DETECTORS

1.0 INTRODUCTION

The data in this report are the results of further measurements made on several doped-silicon detectors in support of the IRAS program. Previous measurements for the IRAS program were reported in NASA Contractor Report No. 151,941, "Characterization of IRAS Doped-Silicon Detectors," December 1976. Funding for this additional work was provided by NASA Purchase Request No. A-39498B from Ames Research Center.

This report presents data on a new Si:Sb detector manufactured by Santa Barbara Research Center (SBRC) as well as new data on several of the previously measured detectors. The data in this report falls into four general sections:

Section 3: Data on the new SBRC Si:Sb detector.

Section 4: Data showing the effects of detector bias on dielectric relaxation.

Section 5: Characterization of spontaneous noise and gamma-induced spikes and their circumvention.

Section 6: Data showing the time response of two detectors to step changes in the background photon flux density.

Section 5 should be of particular interest since little data on transient phenomena are readily available. The data contained in Section 6 is quite extensive and indicates several potential system problems.

2.0 MEASUREMENT CONSIDERATIONS

A complete description of the measurement apparatus and electronics was given in the previous report. The experimental set-up for the measurements reported here was identical to that previously used with one minor exception. While all data in the previous report were obtained with the cold MOSFET pre-amplifier operation as a source follower, some of the data in this report were obtained operating the MOSFET as the input stage of a transimpedance amplifier (TIA). In the TIA configuration the detector load resistor becomes the resistor in the feedback loop. This results in an increase in system bandwidth. The bandwidth in the TIA configuration is limited by the value of the feedback resistor and its shunt capacitance.

Data was obtained at very low background photon flux densities in several instances. This data is labeled "ZILCH" on the graphs. This term is used to indicate the lowest possible photon flux density available in a given measurement apparatus. For the data reported here, a zilch background is less than 2×10^7 photons per second per cm^2.

3.0 SBRC Si:Sb DETECTOR MEASUREMENTS

The data presented in this Section were obtained in exactly the same manner as previously reported data. Spectral response, frequency response, noise spectra, etc., are shown in Figs. 1-12. The gap in the spectral response (Fig. 1) between 34.5 and 36.0 microns was due to a lack of energy caused by atmospheric water vapor absorption. The residual long wavelength response (greater than 30μm) is approximately 10%. Note that the optimum bias data shown in Fig. 2 was obtained at an operating temperature of 4.5K. While the optimum bias at 4.5K is 9 volts, there is evidence (see Section 5.3) that higher biases might be advantageous at lower temperatures. The signal wave-shape shown in Fig. 11 may be of interest. Spontaneous noise spikes are clearly shown in Figs. 10, 11, and 12.

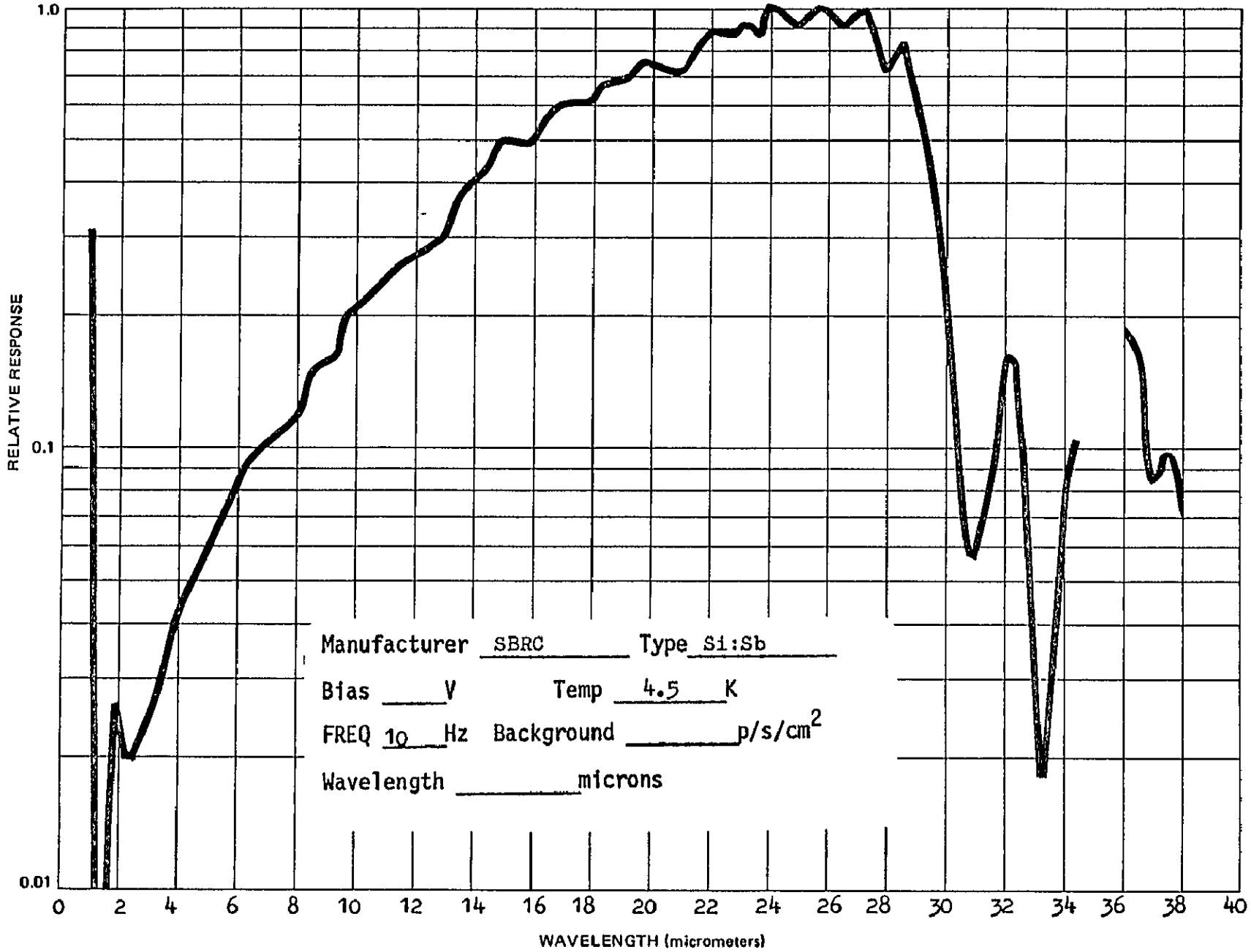

1.0
0.1
0.01
RELATIVE RESPONSE
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
WAVELENGTH (micrometers)
Manufacturer SBRC Type Si:Sb
Bias ____V Temp 4.5 K
FREQ 10 Hz Background _____p/s/cm2
Wavelength _____microns

Figure 1

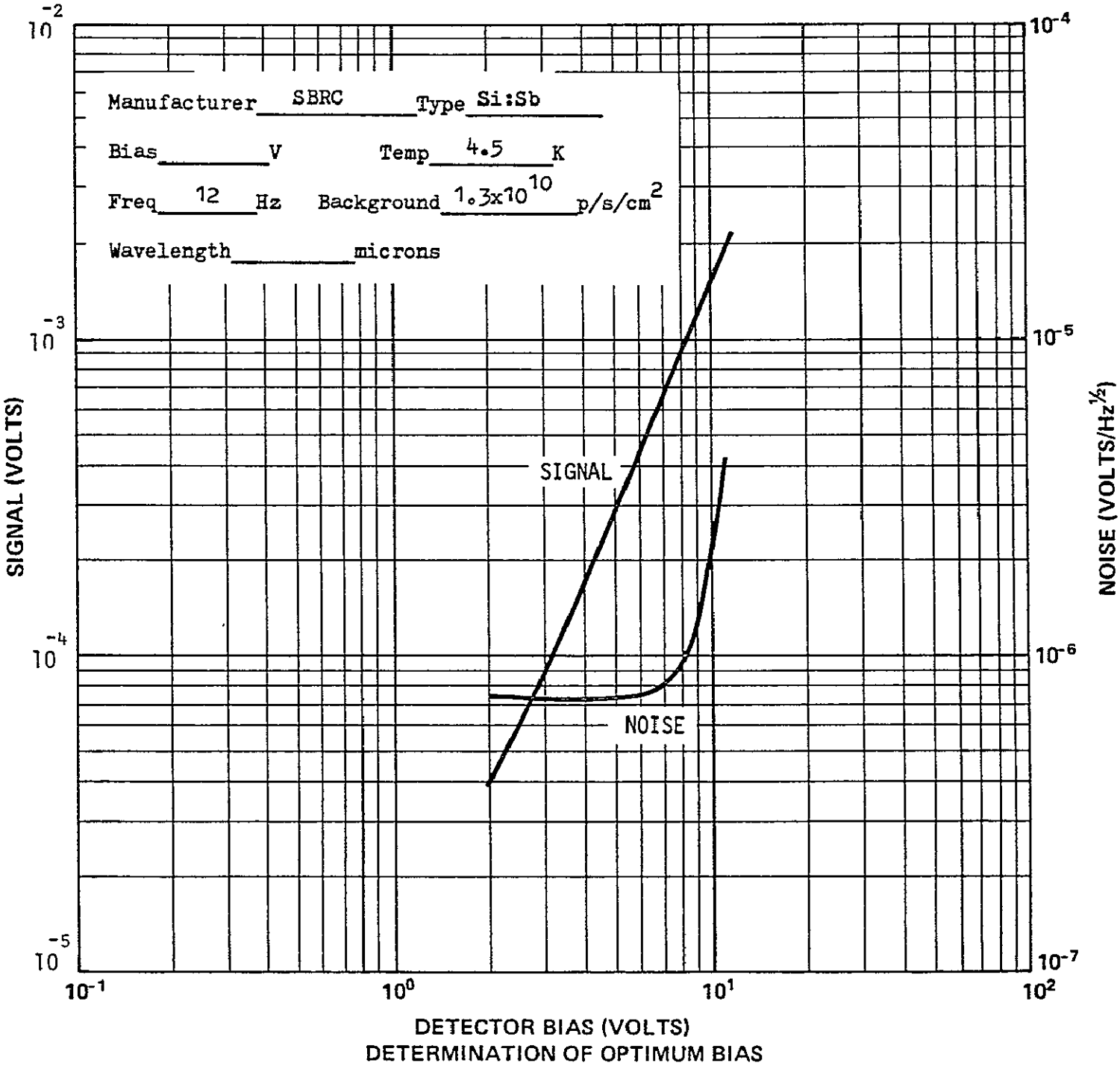
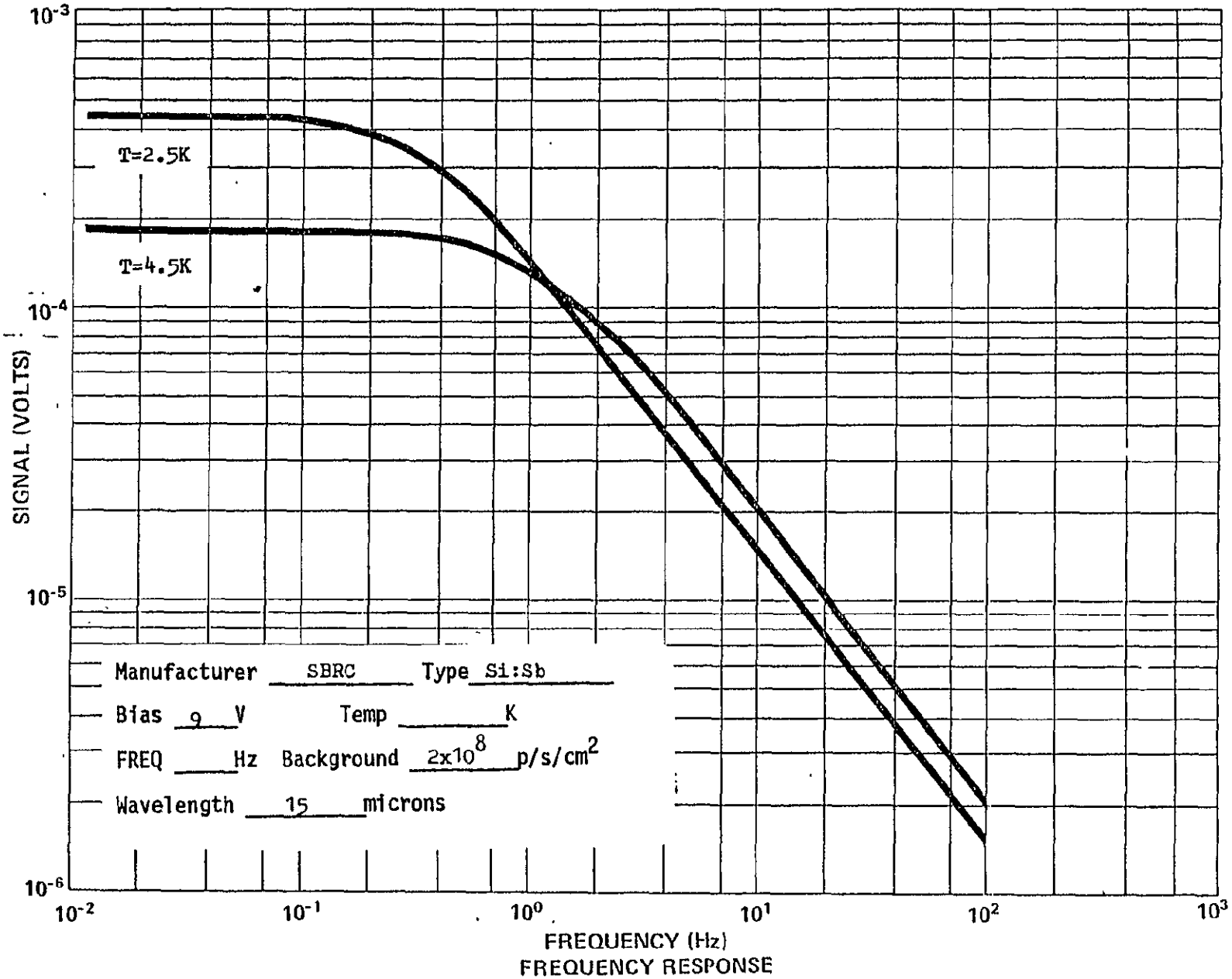

Manufacturer SBRC Type Si:Sb
Bias V Temp 4.5 K
Freq 12 Hz Background 1.3x10^10 p/s/cm^2
Wavelength microns
SIGNAL
NOISE
SIGNAL (VOLTS)
NOISE (VOLTS/Hz^1/2)
DETECTOR BIAS (VOLTS)
DETERMINATION OF OPTIMUM BIAS

Figure 2



FREQUENCY RESPONSE

Figure 3

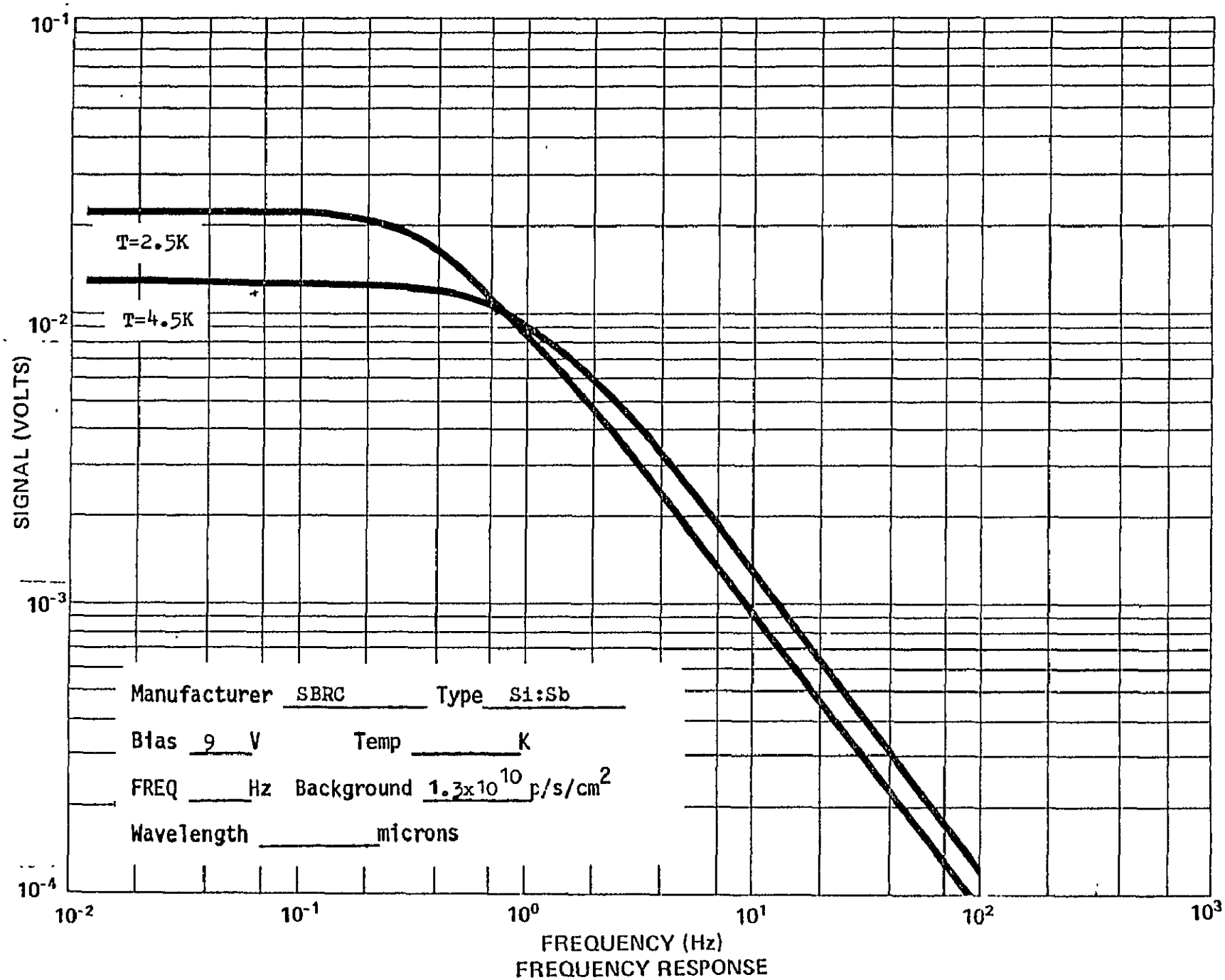
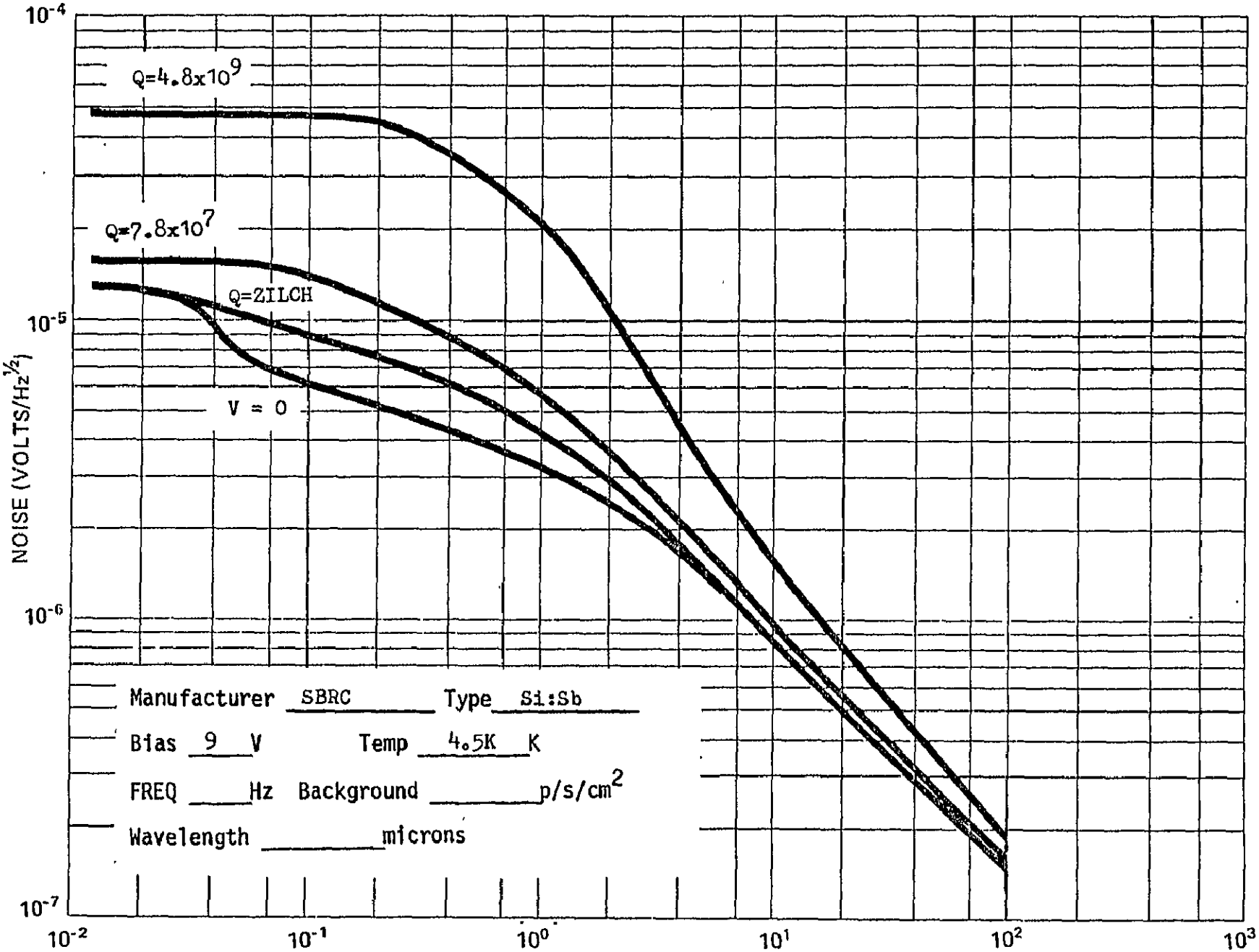
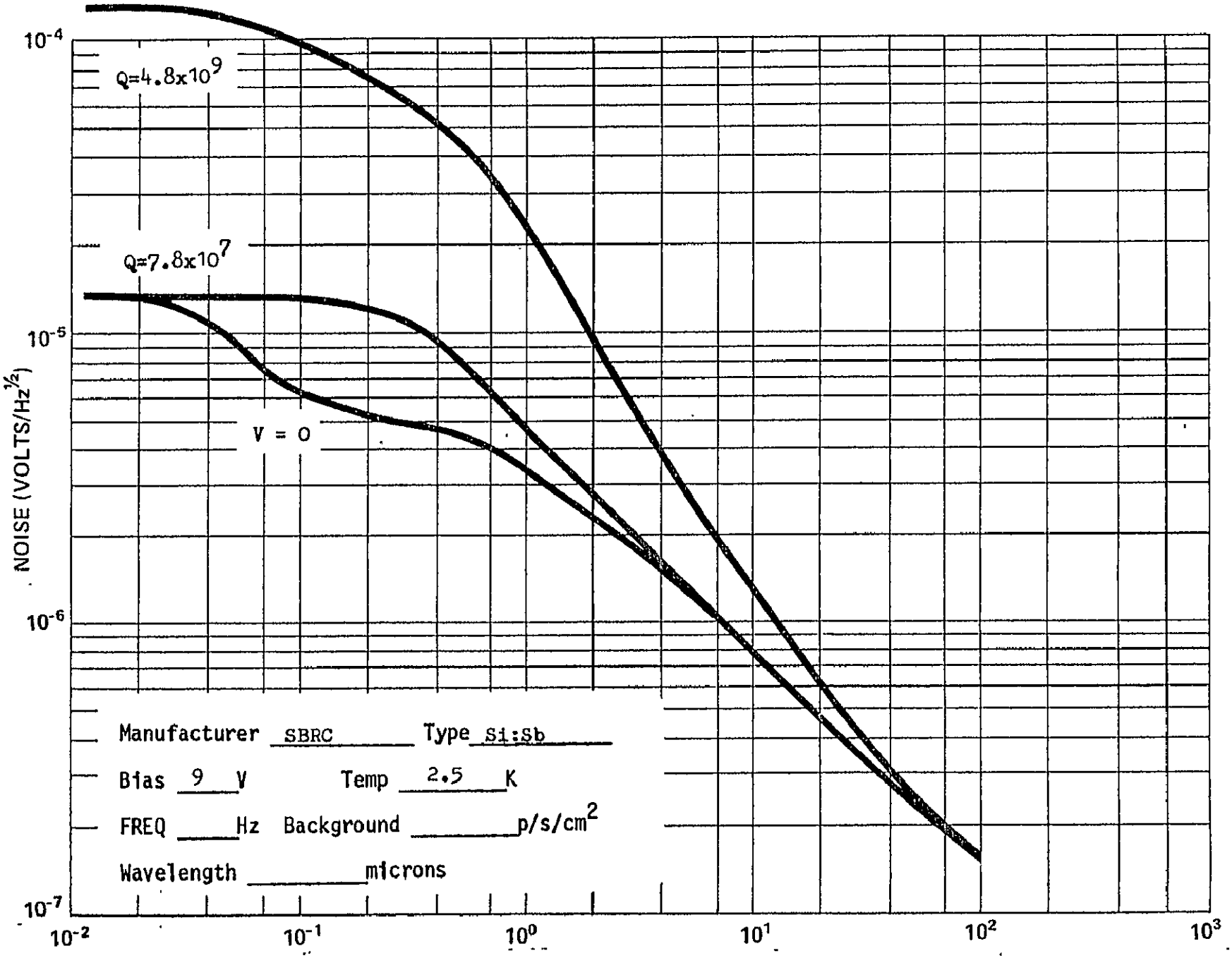

10^{-1}
10^{-2}
10^{-3}
10^{-4}
SIGNAL (VOLTS)
T=2.5K
T=4.5K
Manufacturer SBRC Type Si:Sb
Bias 9 V Temp K
FREQ Hz Background 1.3×10^{10} p/s/cm^2
Wavelength microns
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
FREQUENCY (Hz)
FREQUENCY RESPONSE

Figure 4



NOISE SPECTRUM

Figure 5



NOISE SPECTRUM

Figure 6

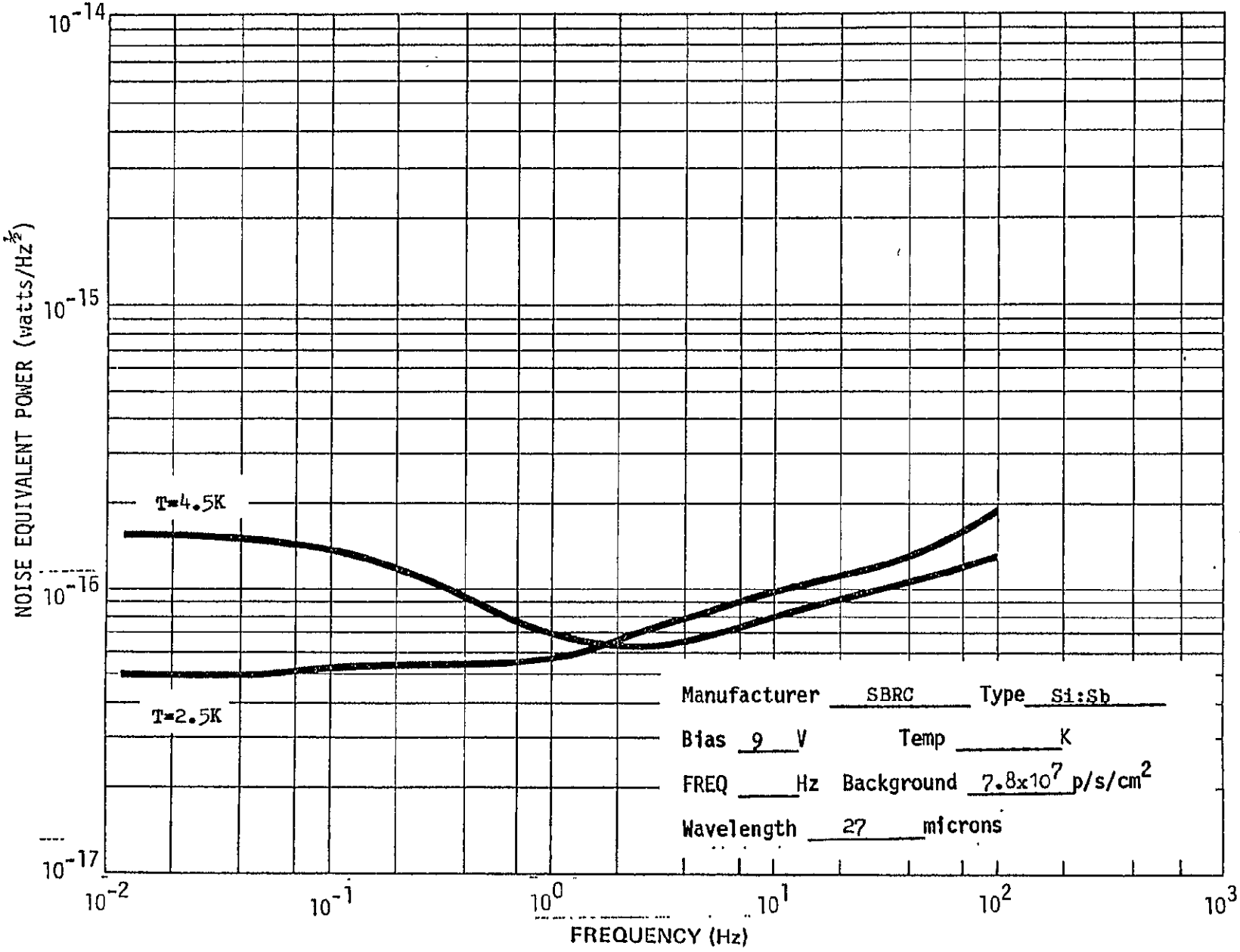

NOISE EQUIVALENT POWER (watts/Hz$^{\frac{1}{2}}$)
10^{-14}
10^{-15}
10^{-16}
10^{-17}
T=4.5K
T=2.5K
Manufacturer SBRC Type Si:Sb
Bias 9 V Temp ____ K
FREQ ____ Hz Background 7.8×10^7 p/s/cm^2
Wavelength 27 microns
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
FREQUENCY (Hz)

Figure 7

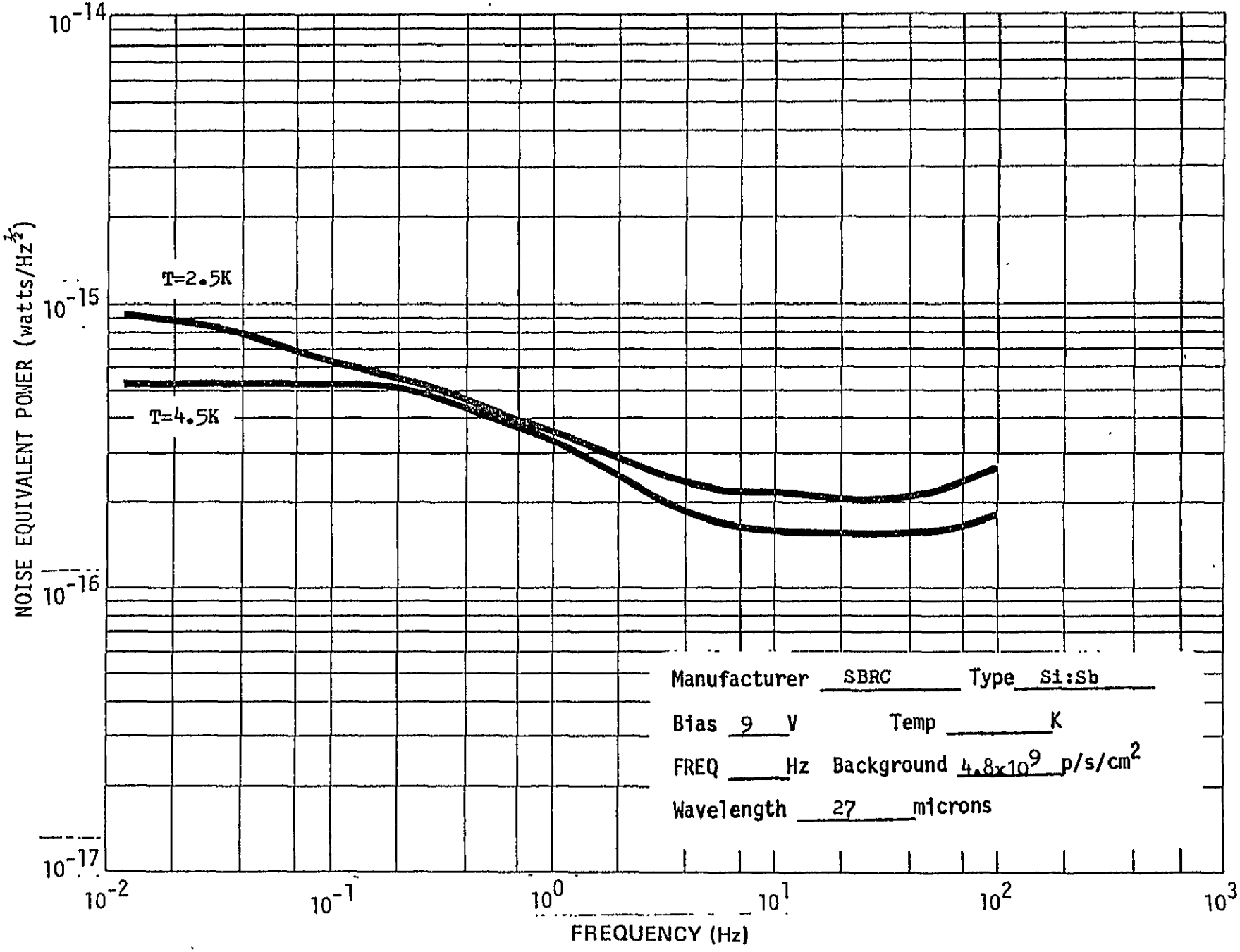

NOISE EQUIVALENT POWER (watts/Hz$^{\frac{1}{2}}$)
10^{-14}
10^{-15}
10^{-16}
10^{-17}
T=2.5K
T=4.5K
Manufacturer SBRC Type Si:Sb
Bias 9 V Temp ____ K
FREQ ____ Hz Background 4.8×10^9 p/s/cm^2
Wavelength 27 microns
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
FREQUENCY (Hz)

Figure 8

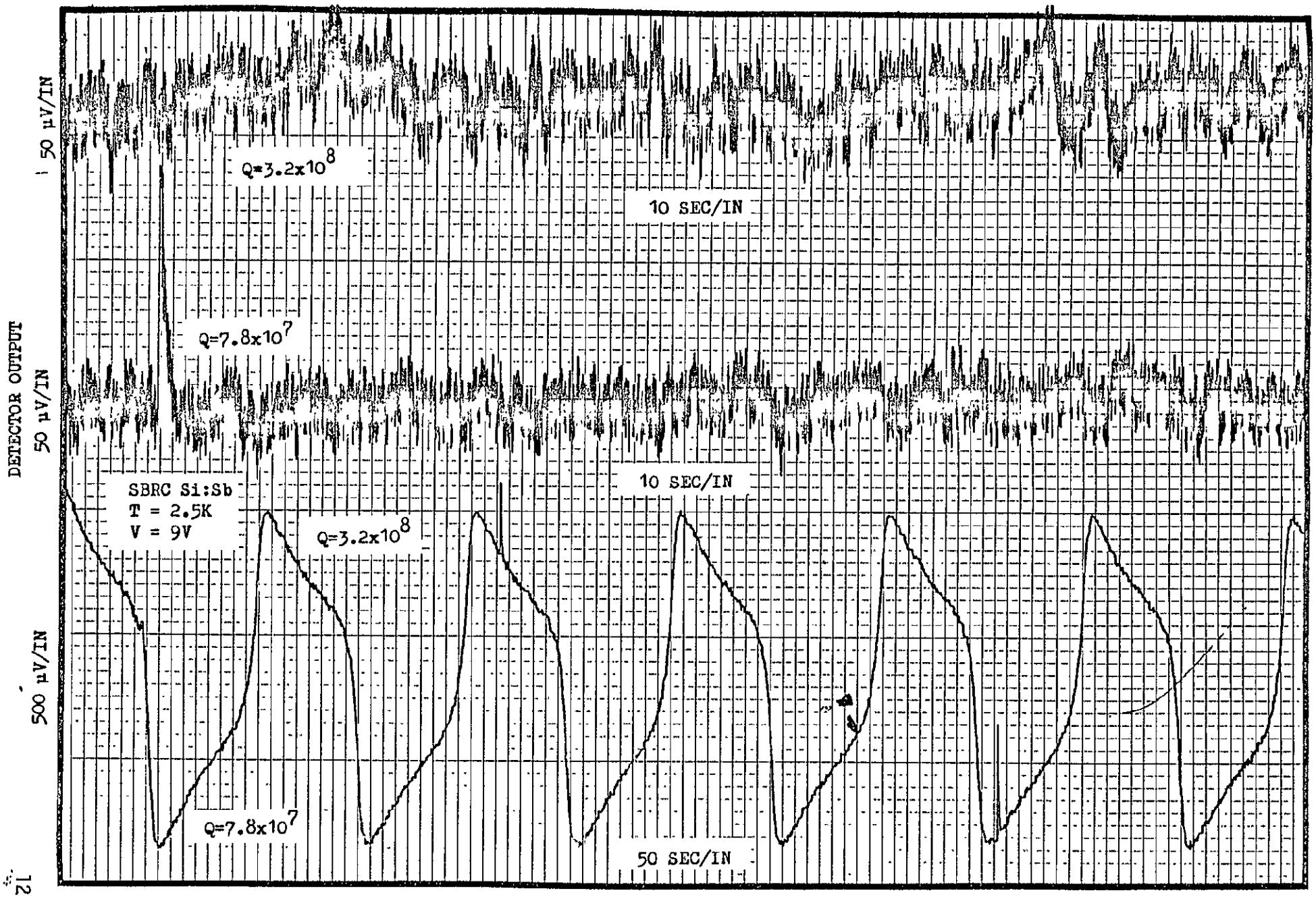

DETECTOR OUTPUT
50 μV/IN
50 μV/IN
500 μV/IN
Q=3.2x10^8
Q=7.8x10^7
10 SEC/IN
SBRC Si:Sb
T = 2.5K
V = 9V
Q=3.2x10^8
10 SEC/IN
Q=7.8x10^7
50 SEC/IN
TIME

Figure 9

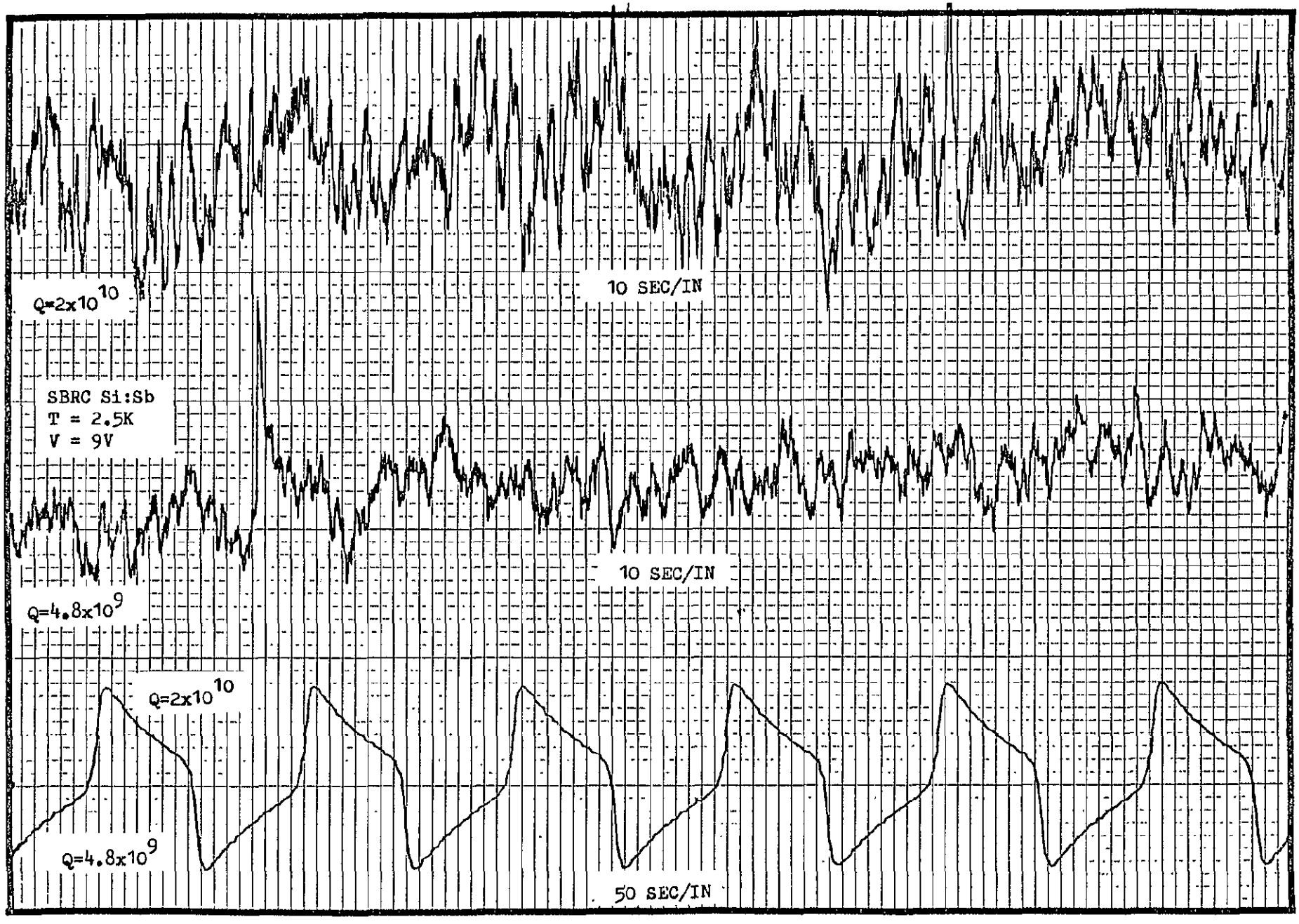

DETECTOR OUTPUT
200 μV/IN
200 μV/IN
50 mV/IN
Q=2x10^10
SBRC Si:Sb
T = 2.5K
V = 9V
10 SEC/IN
Q=4.8x10^9
10 SEC/IN
Q=2x10^10
Q=4.8x10^9
50 SEC/IN
TIME

Figure 10

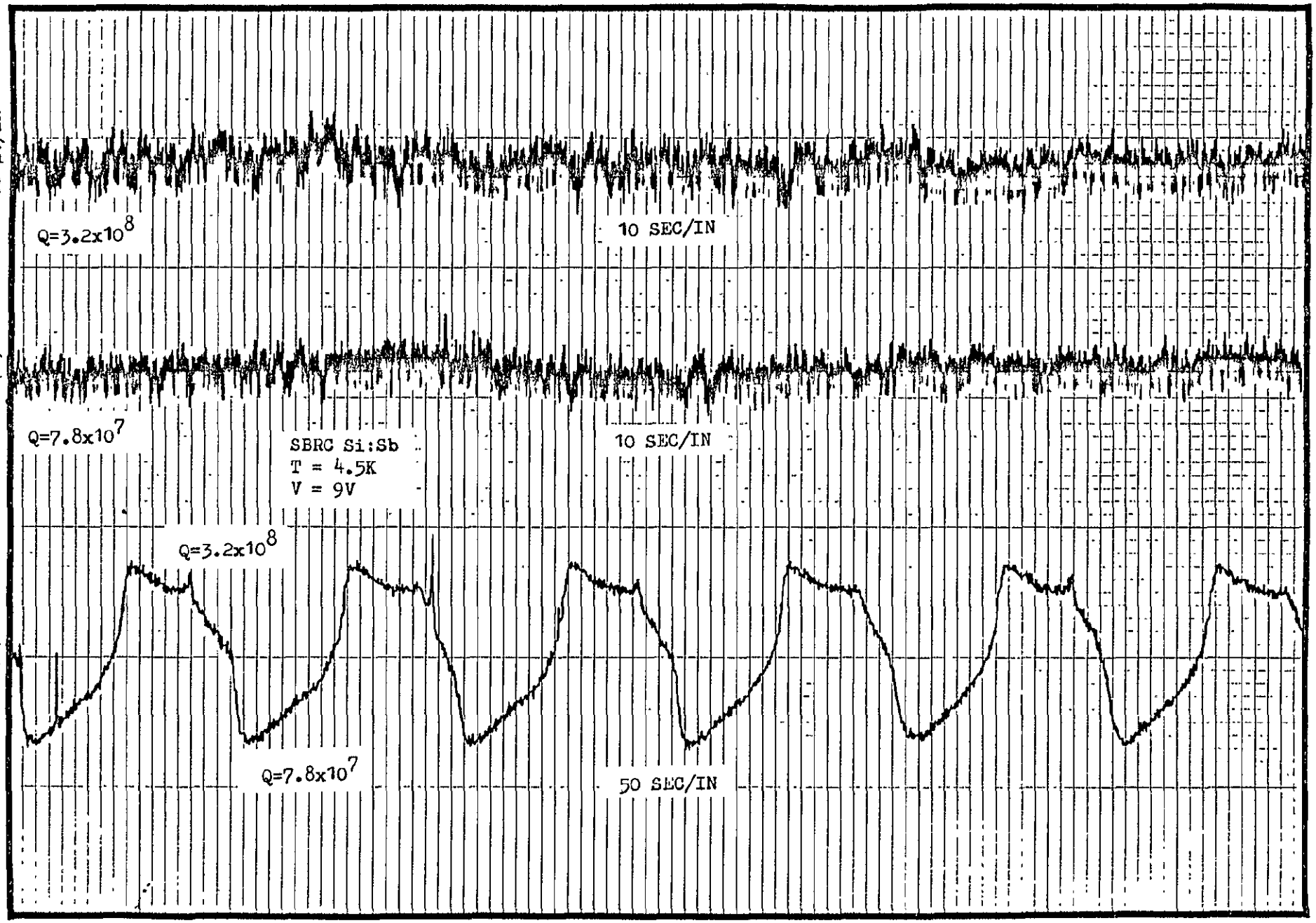

DETECTOR OUTPUT
100 μV/IN
100 μV/IN
400 μV/IN
Q=3.2x10^8
Q=7.8x10^7
SBRC Si:Sb
T = 4.5K
V = 9V
10 SEC/IN
10 SEC/IN
Q=3.2x10^8
Q=7.8x10^7
50 SEC/IN
TIME

Figure 11

KEUFFEL & ESSER CO. MADE IN U.S.A.

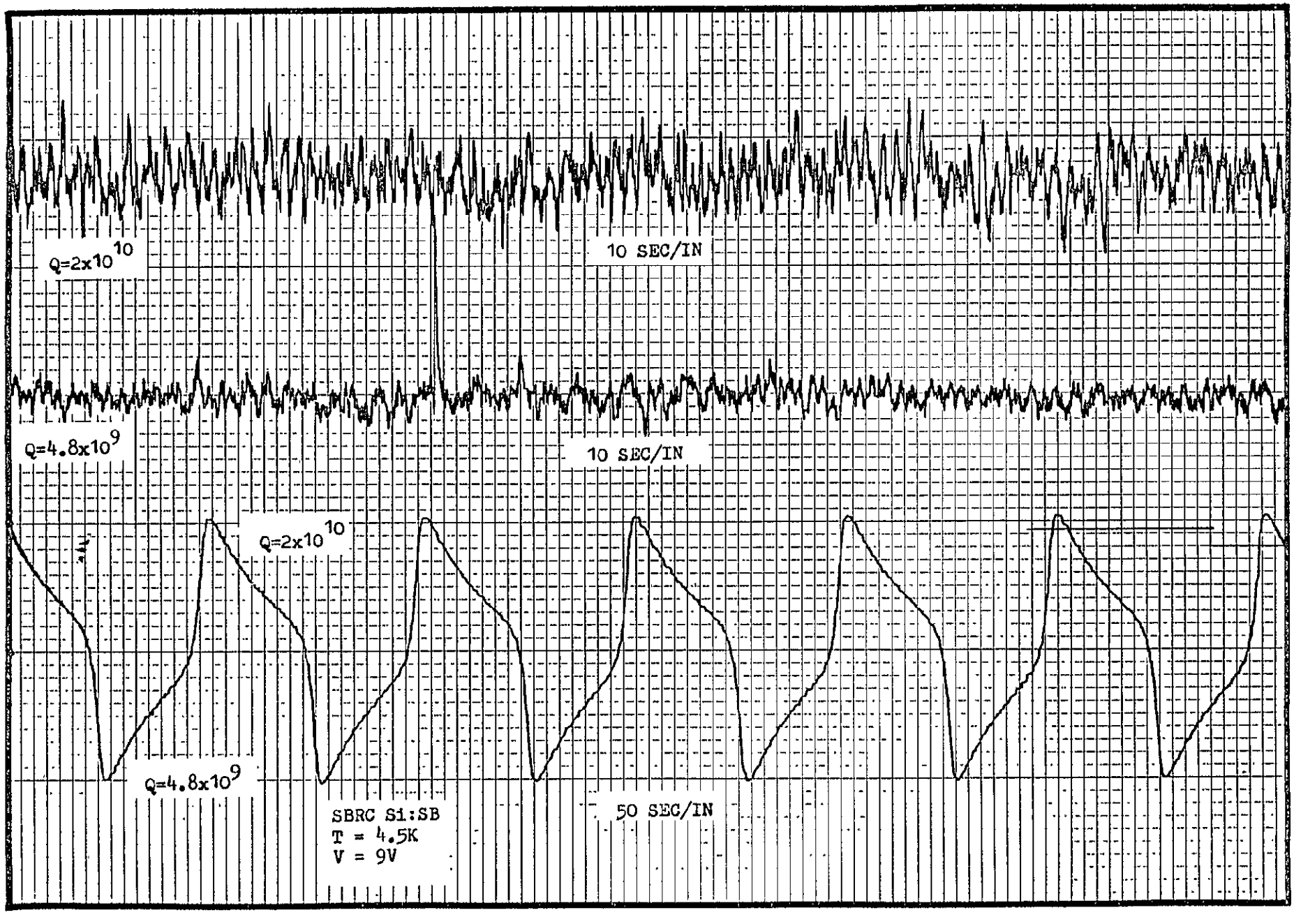


Figure 12

4.0 DIELECTRIC RELAXATION EFFECTS

All extrinsic photoconductors operating under reduced photon backgrounds exhibit an effect known as "dielectric relaxation." A detector will have a high responsivity at low frequencies and a low responsivity at high frequencies. The frequency at which the transition between the two responsivities occurs seems to be related to the electrical conductivity of the detector. Detector conductivity, in turn, is a function of bias voltage, background photon, flux, and operating temperature.

To illustrate the effect of these three variables on the dielectric relaxation frequency, each parameter was varied while measuring the frequency response of two detectors between 0.012 and 12.0 Hz. Data for a RIC/MSD Si:Sb detector are shown in Figs. 13-16 and data for a SBRC Si:As detector are shown in Figs. 17-20. For each detector, measurements were made at two backgrounds, two operating temperatures, and several bias voltages. Measurements at the higher background were made using a TIA. A source follower configuration was used at the lower background. The dotted lines on the lower background graphs indicate the true detector response (correction was made for the input RC roll-off of the MOSFET). Note that for both detectors, the transition frequency between the low and high frequency responsivities moves to higher frequency with increasing background, temperature, and bias. Also for a fixed background and temperature, the ratio between the high and low frequency responsivities increases with increasing bias voltage.

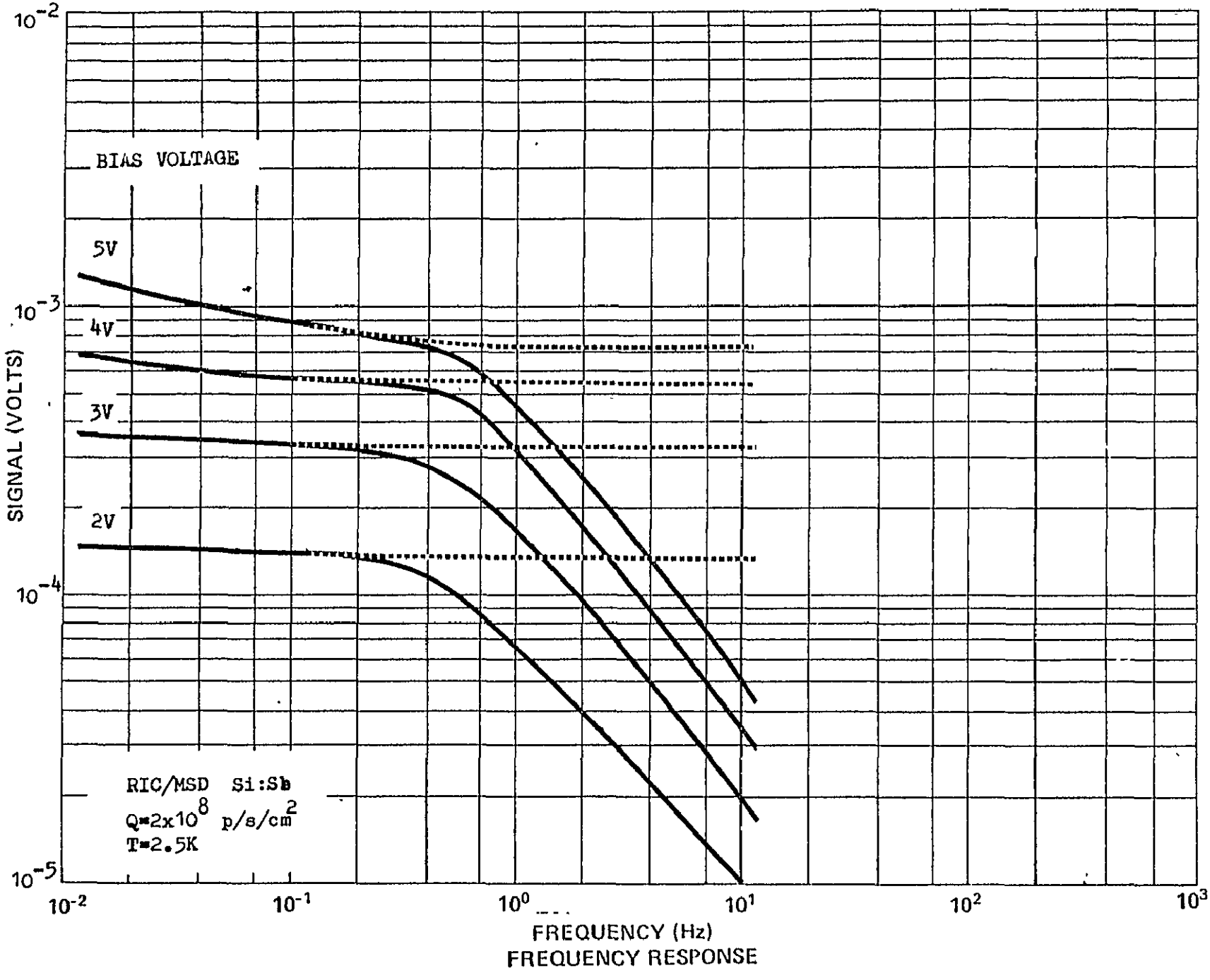
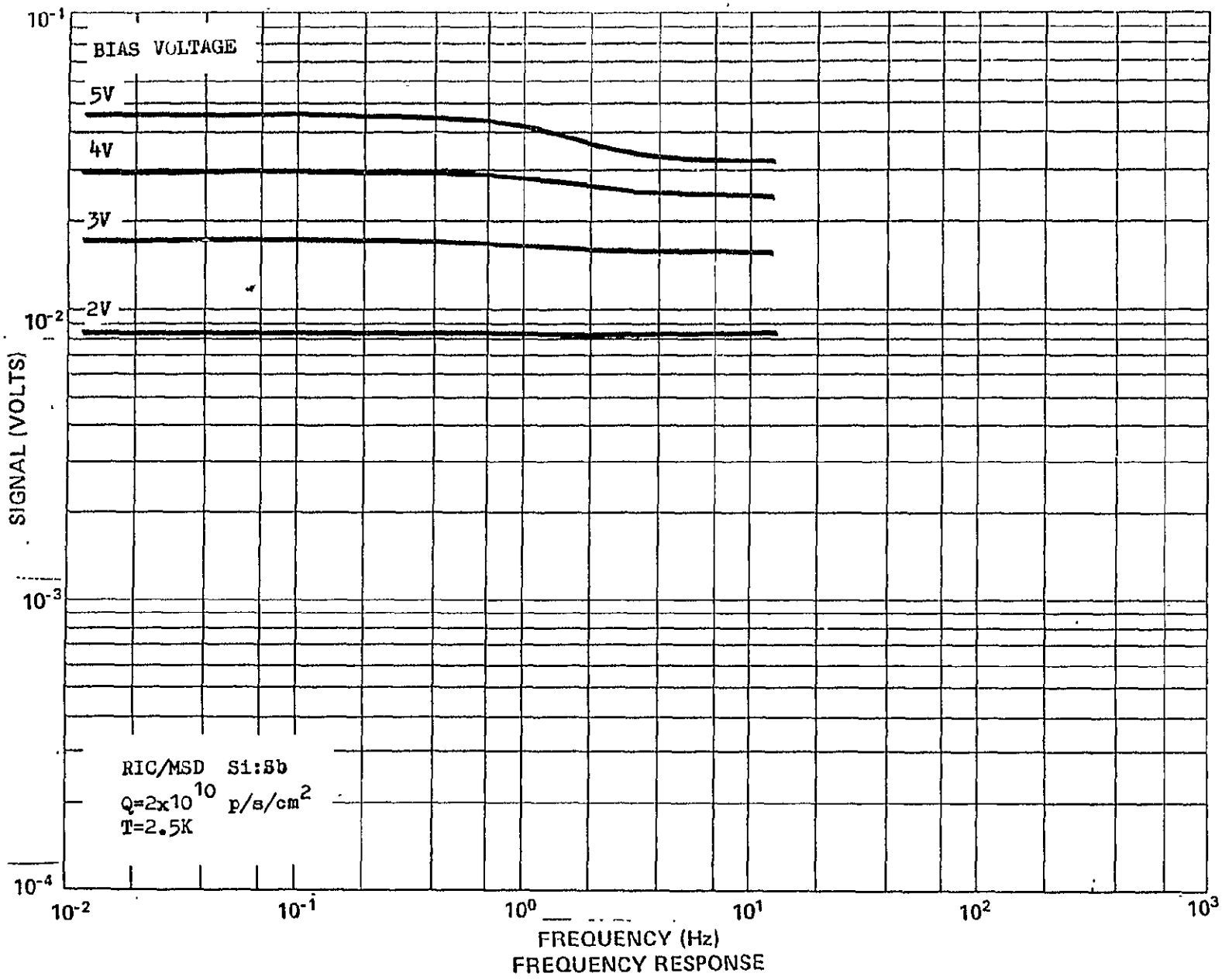

BIAS VOLTAGE
5V
4V
3V
2V
RIC/MSD Si:Sb
Q=2x10^8 p/s/cm^2
T=2.5K
SIGNAL (VOLTS)
10^-2
10^-3
10^-4
10^-5
10^-2
10^-1
10^0
10^1
10^2
10^3
FREQUENCY (Hz)
FREQUENCY RESPONSE

Figure 13



FREQUENCY RESPONSE

Figure 14

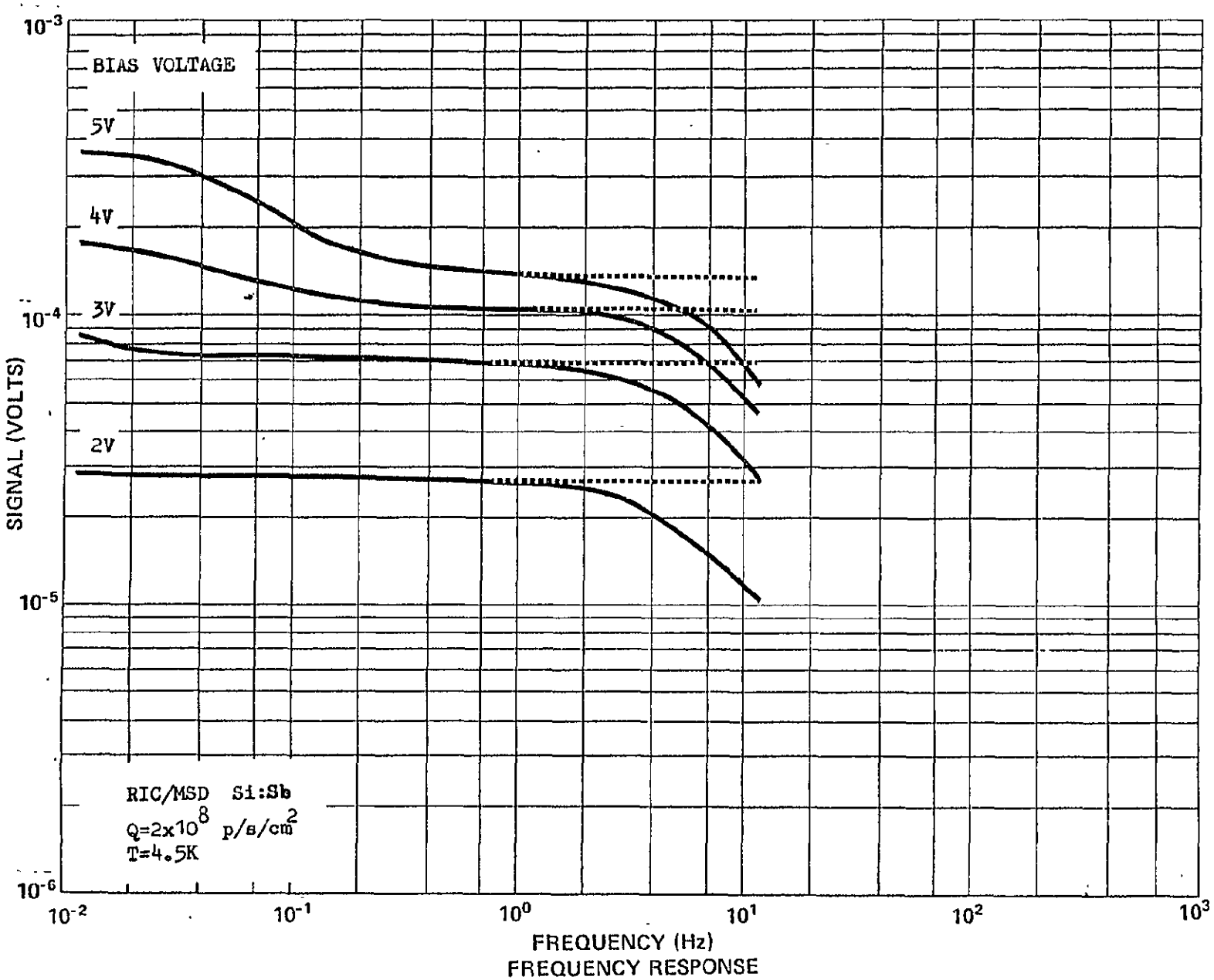
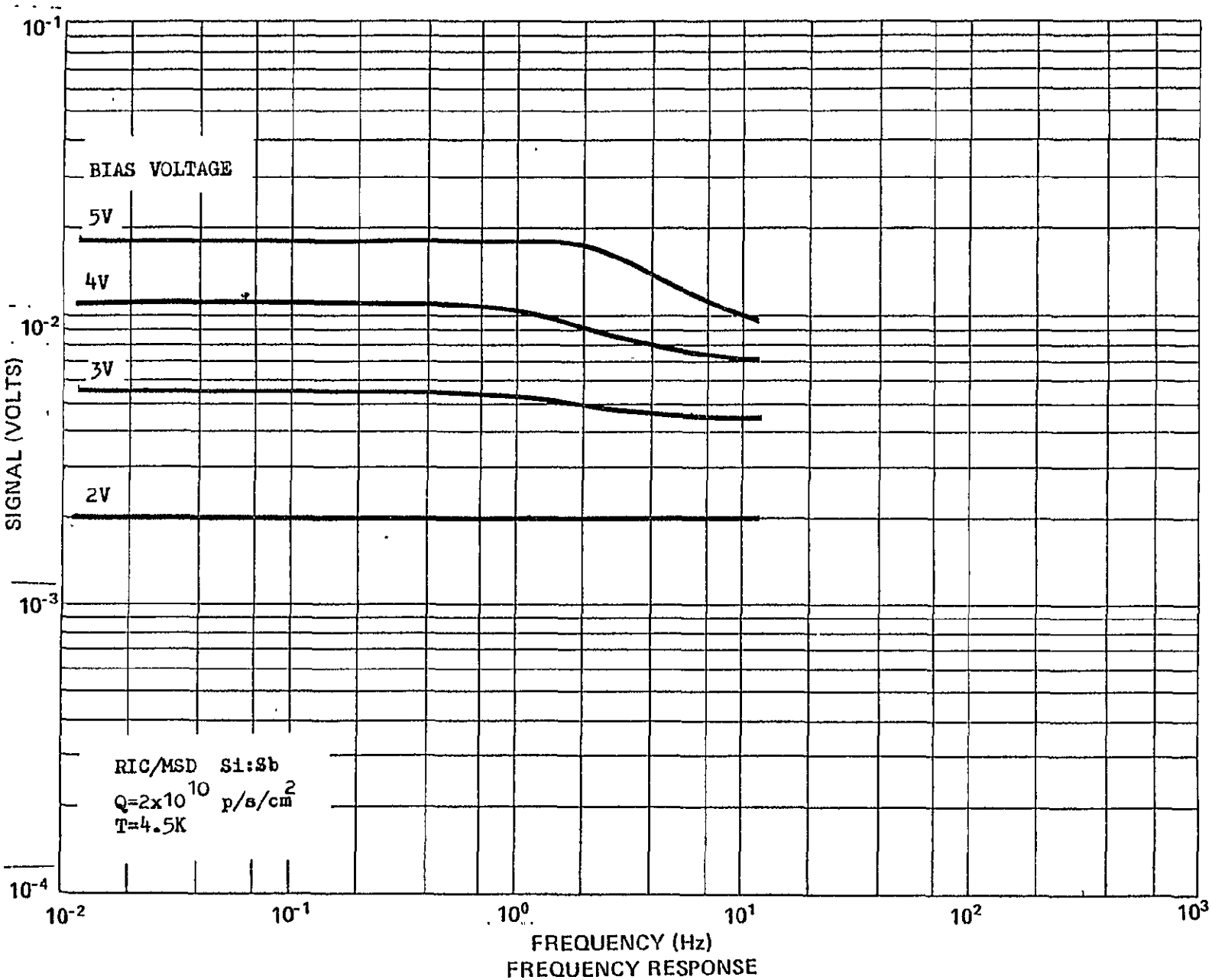
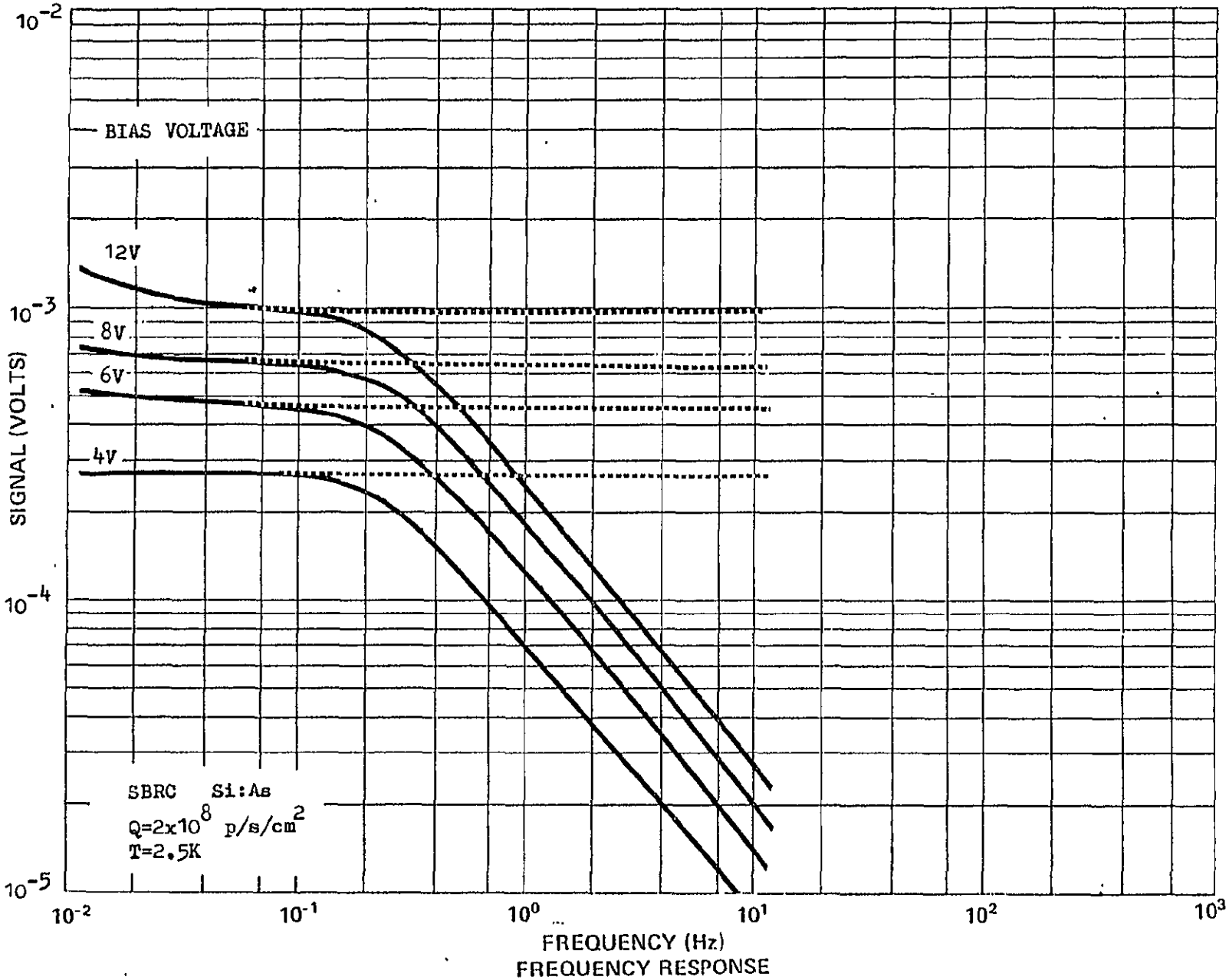

BIAS VOLTAGE
5V
4V
3V
2V
RIC/MSD Si:Sb
Q=2x10^8 p/s/cm^2
T=4.5K
SIGNAL (VOLTS)
FREQUENCY (Hz)
FREQUENCY RESPONSE

Figure 15



FREQUENCY RESPONSE

Figure 16



FREQUENCY RESPONSE

Figure 17

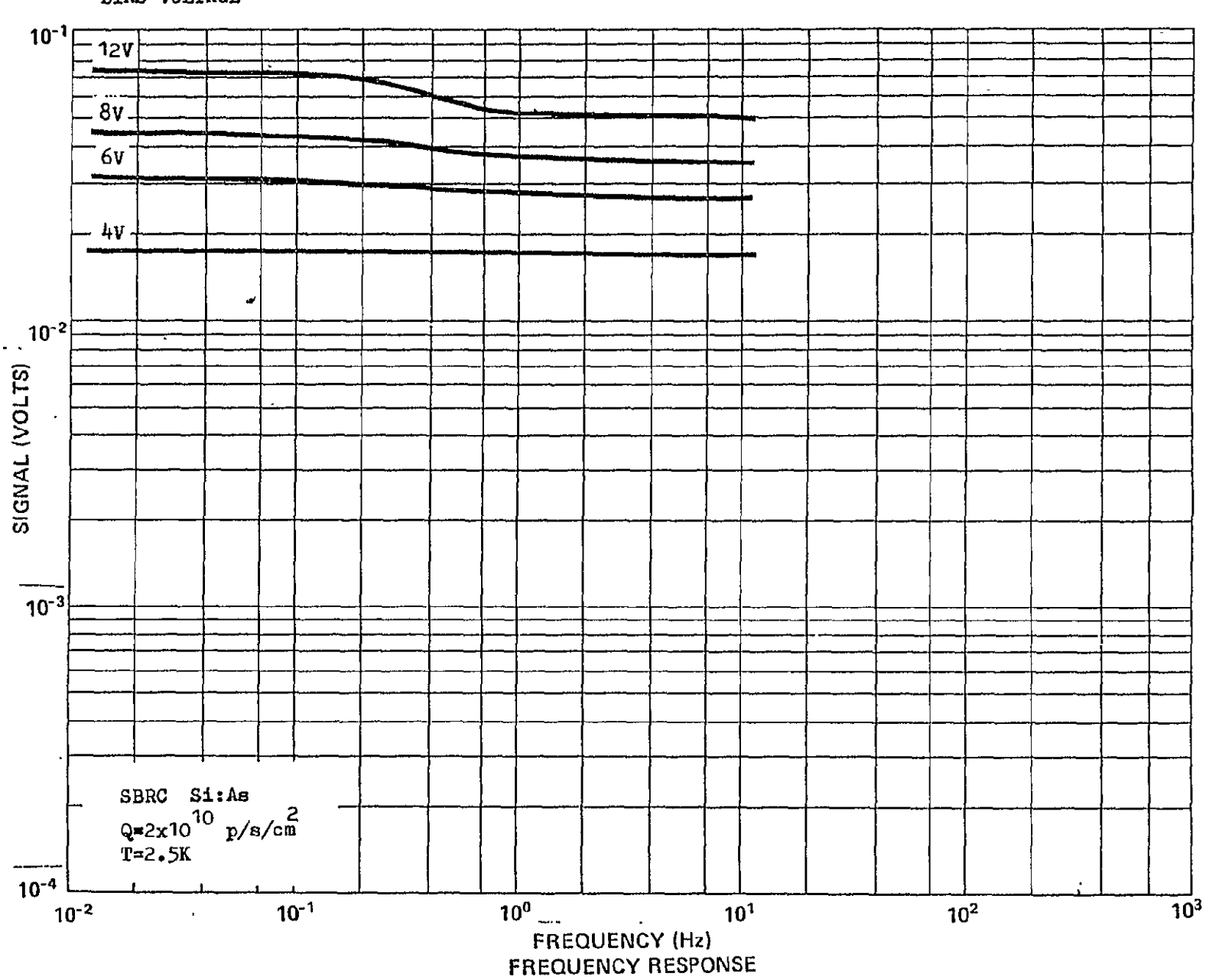
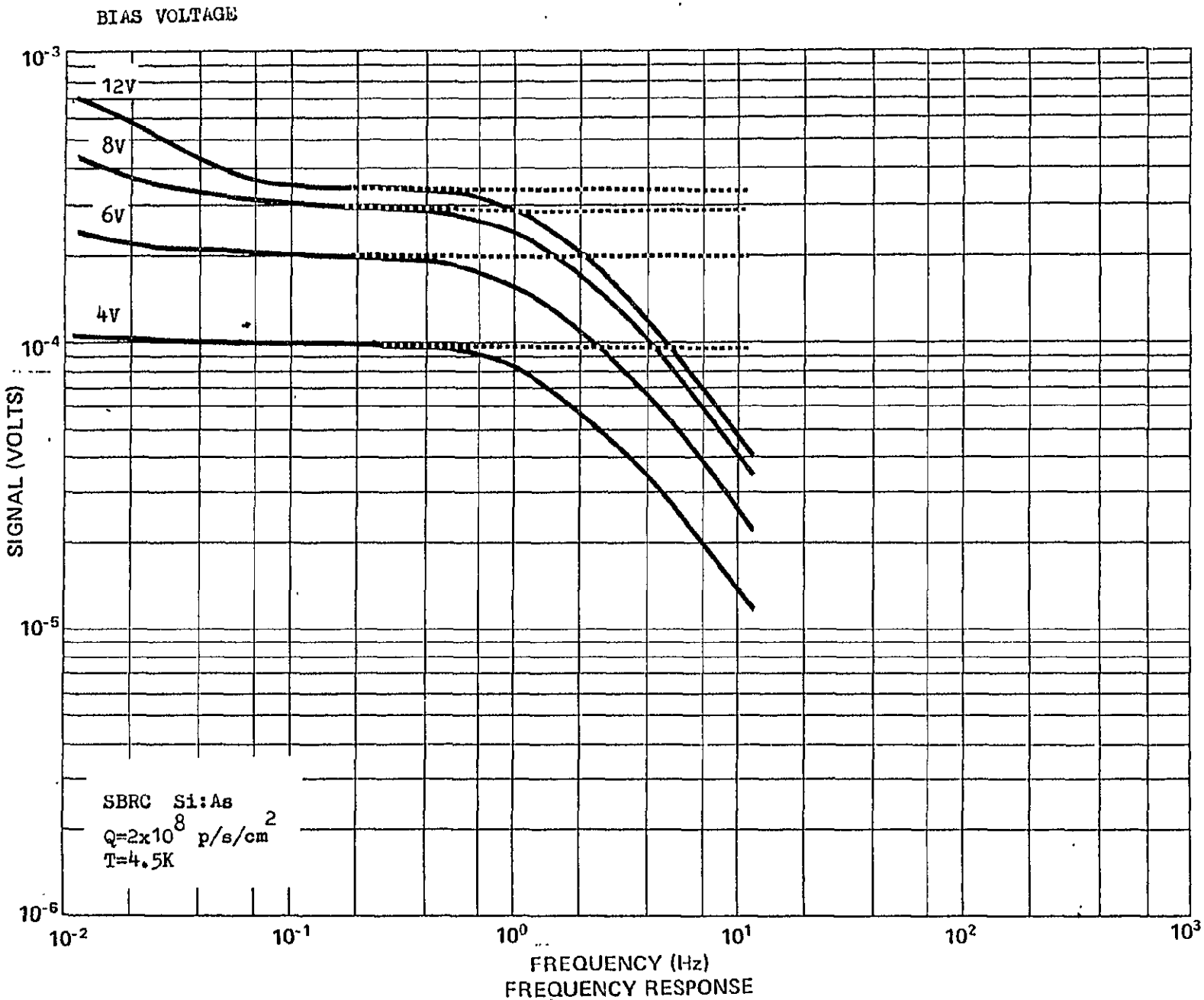
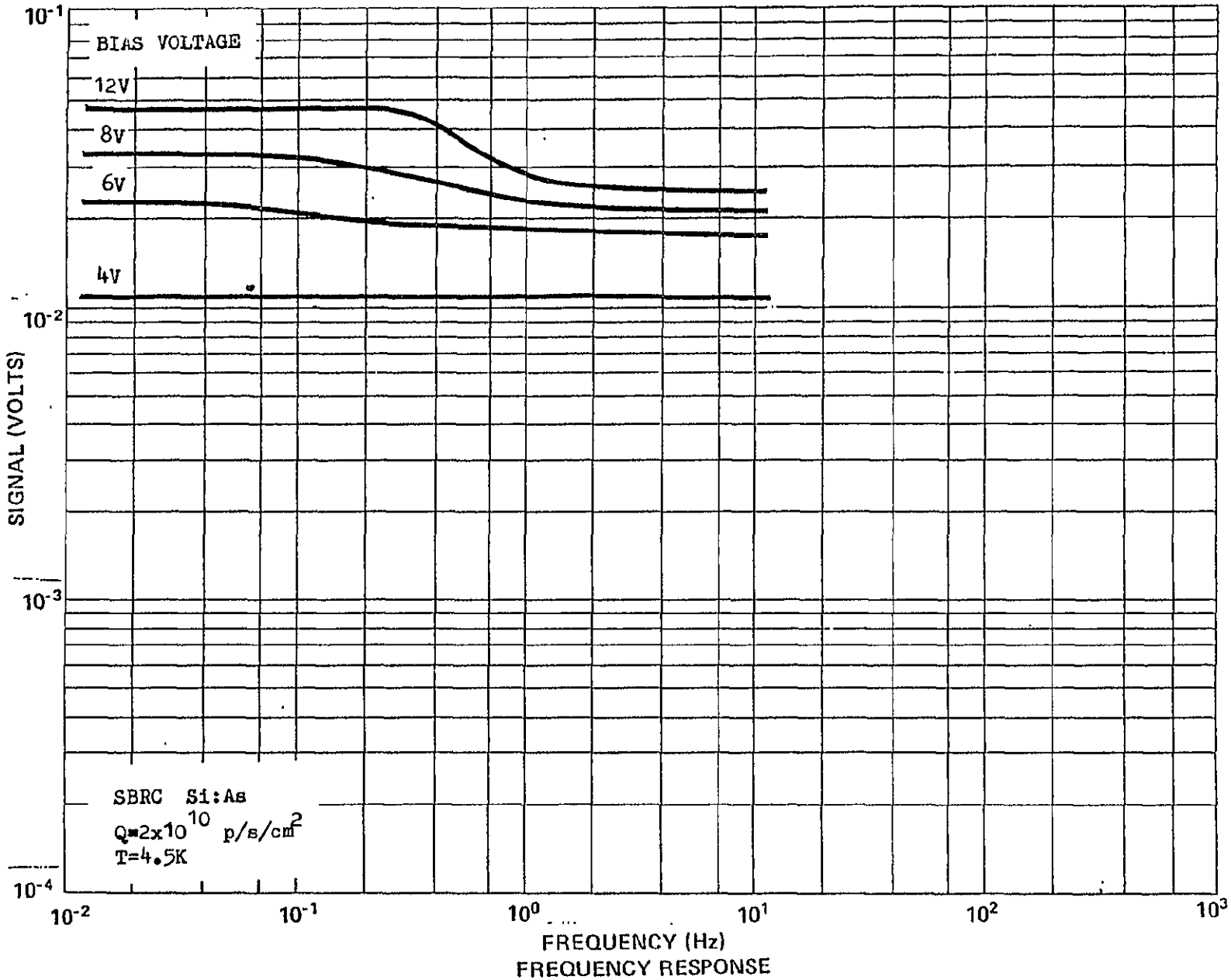

BIAS VOLTAGE
12V
8V
6V
4V
SIGNAL (VOLTS)
10^{-1}
10^{-2}
10^{-3}
10^{-4}
SBRC Si:As
Q=2x10^{10} p/s/cm^2
T=2.5K
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
FREQUENCY (Hz)
FREQUENCY RESPONSE

Figure 18



FREQUENCY RESPONSE

Figure 19



FREQUENCY RESPONSE

Figure 20

5.0 CHARACTERIZATION OF SPONTANEOUS NOISE SPIKES AND GAMMA INDUCED SPIKES

Some extrinsic photoconductors operating in a reduced IR background environment exhibit "spontaneous noise spiking." These noise spikes are usually characterized by a rapid rise time and a decay time set by the system bandwidth. It has been shown that ionizing radiation absorbed in these detectors exhibits similar effects. This Section deals with the characterization of these two types of spikes and with two means of circumventing the noise spike problem. Data were obtained on three different detectors and the data in this Section are grouped by detector.

5.1.0. RIC/MSD Si:P

This detector was chosen for the characterization of spontaneous noise spikes because of its rather high event rate. Gamma-induced spikes were also measured by placing a small Cobalt 60-gamma source close to the detector.

5.1.1. Dependence of Spontaneous Noise Spike Event Rate

A TIA configuration was used to obtain the data in this Section. The output of the TIA was fed into a counter which was triggered by spikes whose amplitudes were greater than the detector noise level. Counts were accumulated for a period of 5 minutes for each data point.

Figure 21 shows the spontaneous noise spike event rate as a function of bias voltage for two temperatures and several backgrounds. The same data are replotted in Figs. 22 and 23 as functions of background at the two temperatures. The event rate is seen to be a strong function of both background and bias, but the functional dependence is different at the two temperatures.

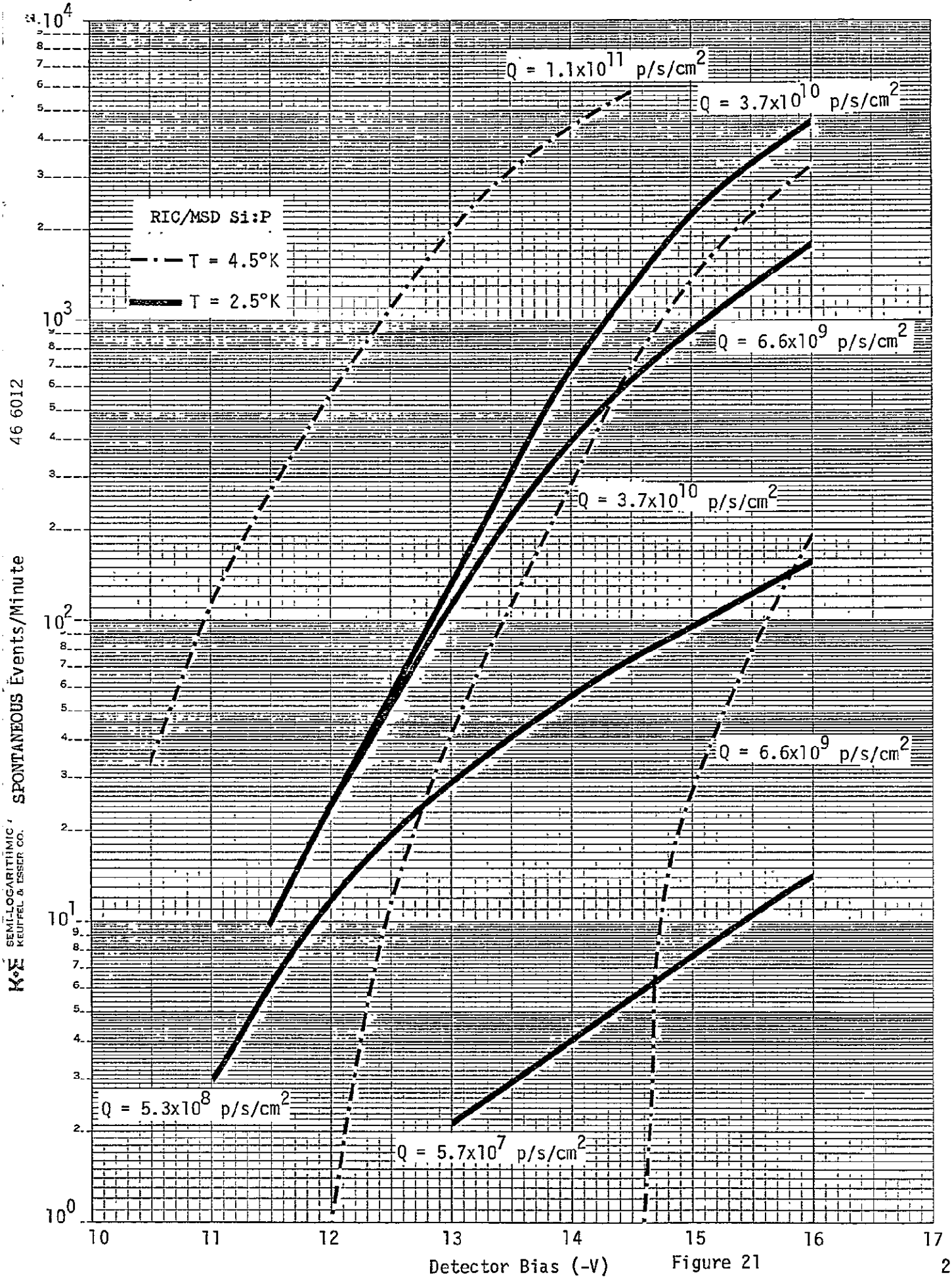

RIC/MSD Si:P
T = 4.5°K
T = 2.5°K
Q = 1.1x10^11 p/s/cm^2
Q = 3.7x10^10 p/s/cm^2
Q = 6.6x10^9 p/s/cm^2
Q = 3.7x10^10 p/s/cm^2
Q = 6.6x10^9 p/s/cm^2
Q = 5.3x10^8 p/s/cm^2
Q = 5.7x10^7 p/s/cm^2
SPONTANEOUS Events/Minute
Detector Bias (-V)
10^4
10^3
10^2
10^1
10^0
10
11
12
13
14
15
16
17
46 6012
K+E SEMI-LOGARITHMIC KEUFFEL & ESSER CO.

Figure 21

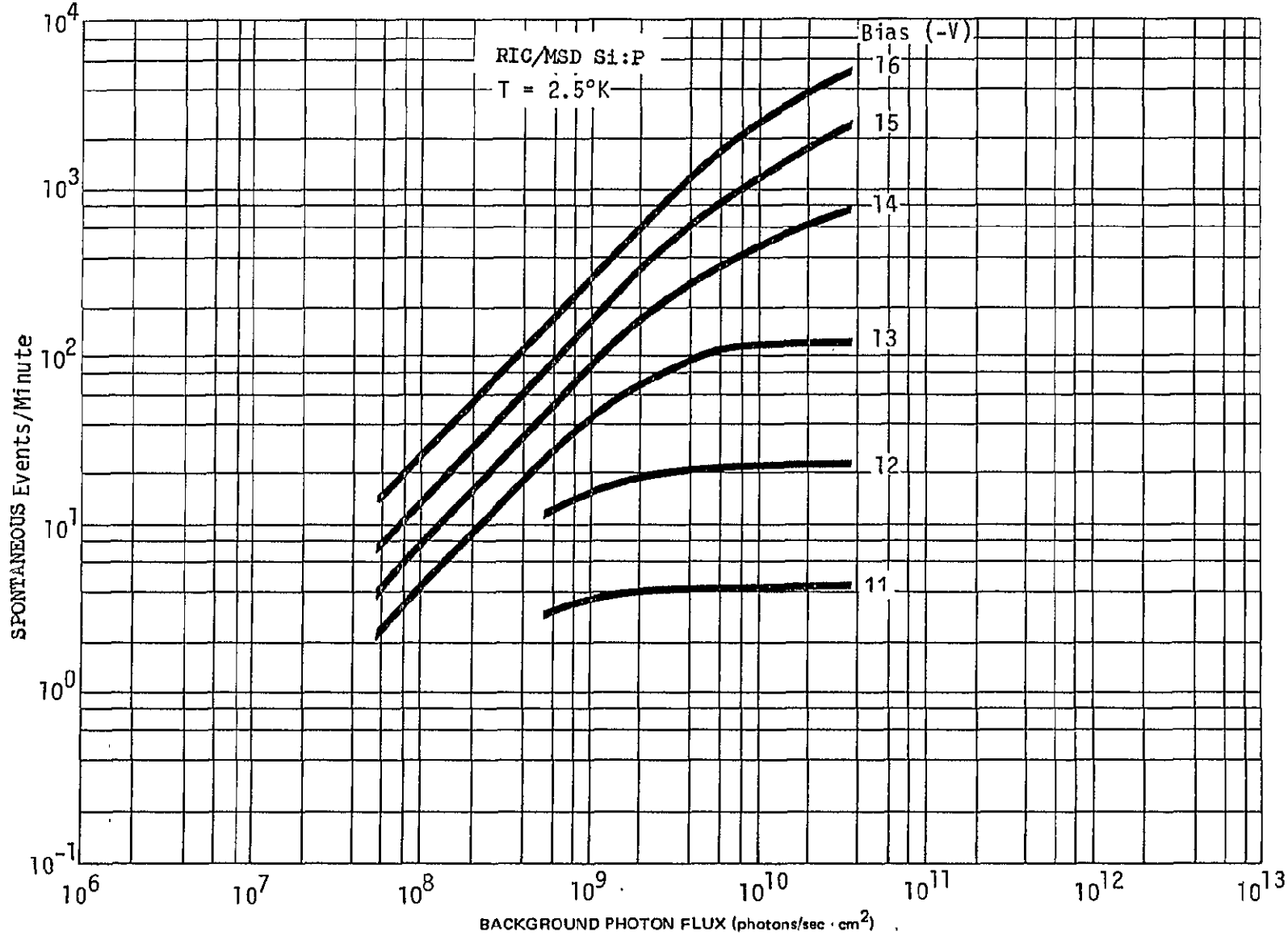

RIC/MSD Si:P
T = 2.5°K
Bias (-V)
16
15
14
13
12
11
SPONTANEOUS Events/Minute
10^4
10^3
10^2
10^1
10^0
10^{-1}
10^6
10^7
10^8
10^9
10^{10}
10^{11}
10^{12}
10^{13}
BACKGROUND PHOTON FLUX (photons/sec · cm^2)

Figure 22

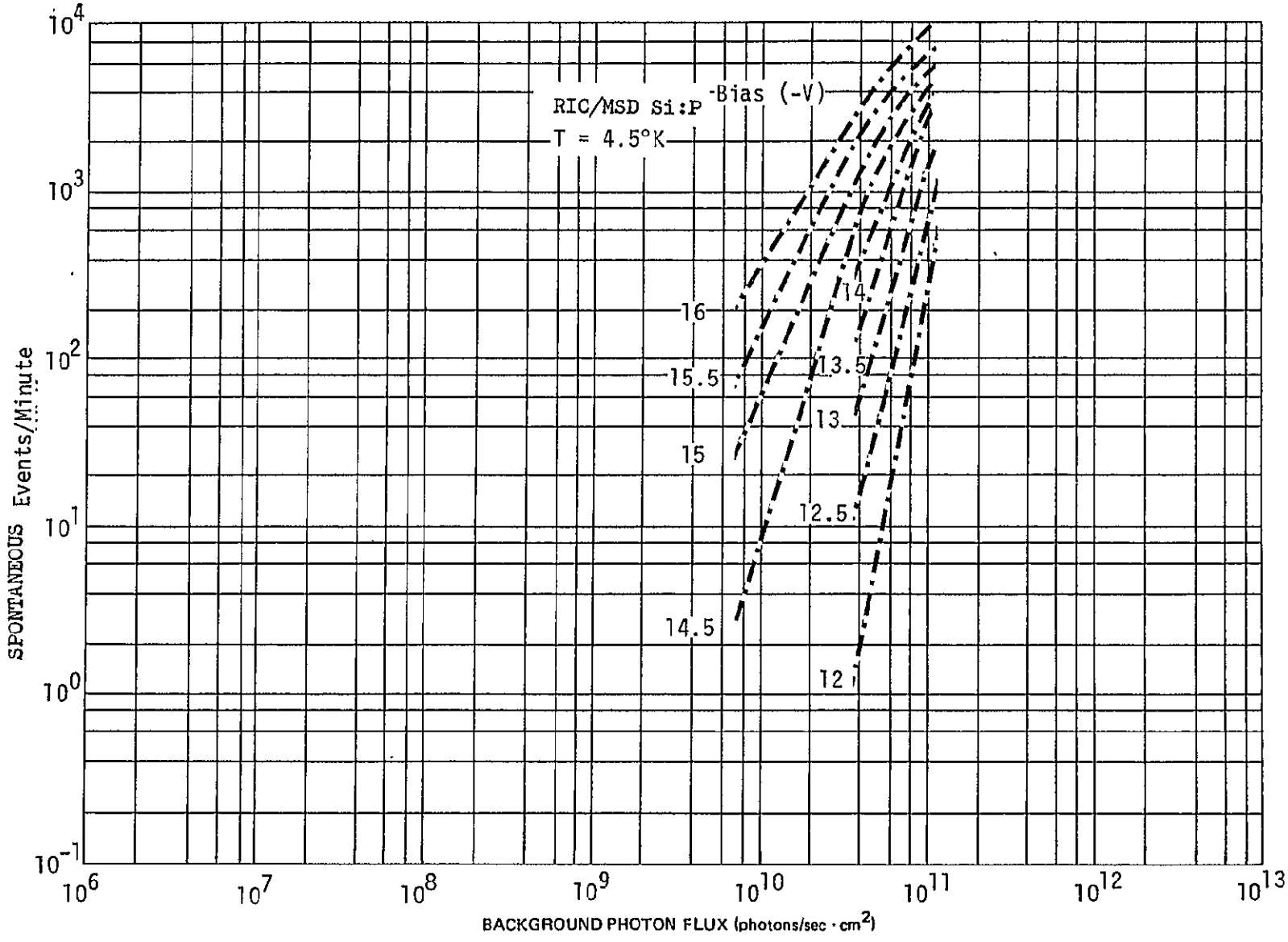

RIC/MSD Si:P
T = 4.5°K
Bias (-V)
16
15.5
15
14.5
14
13.5
13
12.5
12
SPONTANEOUS Events/Minute
BACKGROUND PHOTON FLUX (photons/sec · cm²)
10⁴
10³
10²
10¹
10⁰
10⁻¹
10⁶
10⁷
10⁸
10⁹
10¹⁰
10¹¹
10¹²
10¹³

Figure 23

5.1.2. Spontaneous Noise Spike Pulse Amplitude Distribution

A TIA was used to obtain the data presented in this Section. The output of the TIA was also fed through the trigger circuit of a Hewlett-Packard 5451B Courier Analyzer. The trigger level was set to minimize triggering on "normal" noise. The 5451B performed the amplitude distribution. Figures 24-27 show the resulting spontaneous pulse amplitude distributions at a temperature of 2.5K, at two biases and two backgrounds. These distributions seem to be fairly gaussian with a shift to higher amplitudes with increasing bias.

Figures 28-33 show the pulse amplitude distributions at an operating temperature of 4.5K, two backgrounds, and several biases. Note that the distributions are quite different than those obtained at 2.5K. At the lower backgrounds and at the higher backgrounds with low biases, the amplitudes fall into two groups - one group just above the threshold level and the other group at a higher value. However, at the highest biases and backgrounds, the distributions tend to become continuous. The pulse amplitudes again increase with increasing bias voltage.

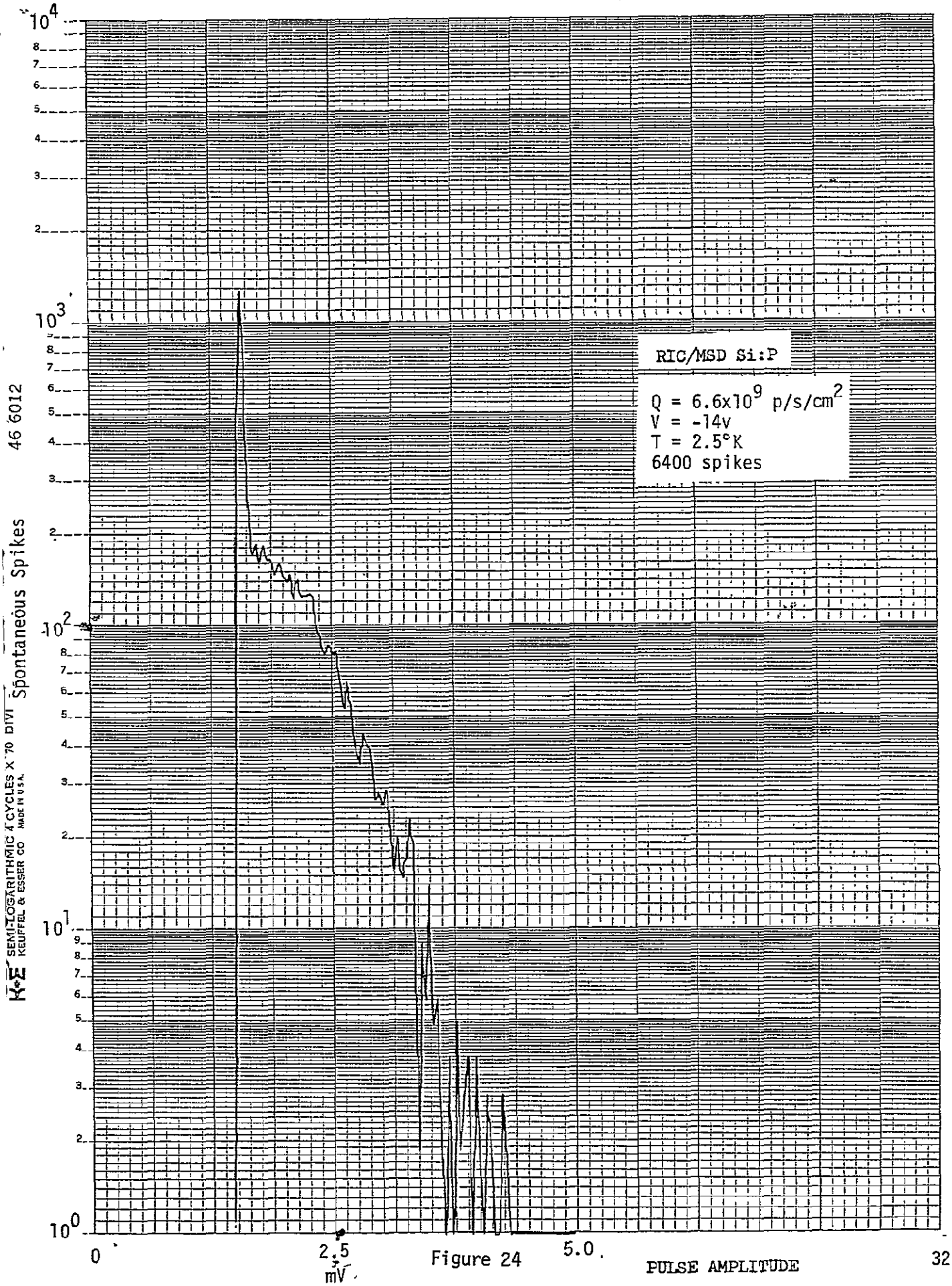

RIC/MSD Si:P
Q = 6.6x10^9 p/s/cm^2
V = -14v
T = 2.5°K
6400 spikes
Spontaneous Spikes
PULSE AMPLITUDE
mV
0
2.5
5.0
46 6012
SEMI-LOGARITHMIC 4 CYCLES X 70 DIVI
KEUFFEL & ESSER CO MADE IN U.S.A.

Figure 24

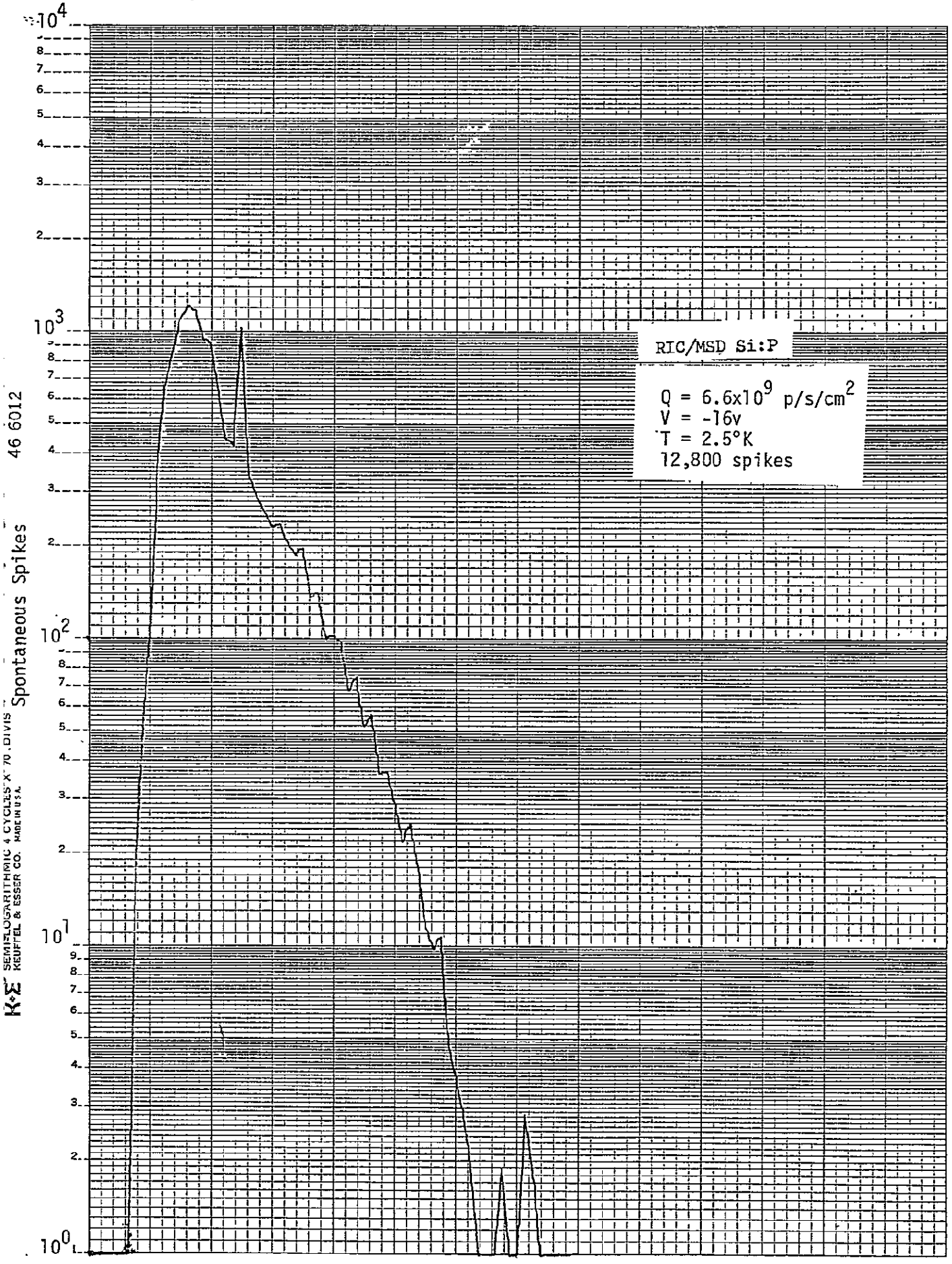

RIC/MSD Si:P
Q = 6.6x10^9 p/s/cm^2
V = -16v
T = 2.5°K
12,800 spikes
Spontaneous Spikes
PULSE AMPLITUDE
mV
0
5.0
10
46 6012
K+E SEMILOGARITHMIC 4 CYCLES X 70 DIVIS
KEUFFEL & ESSER CO. MADE IN U.S.A.

Figure 25

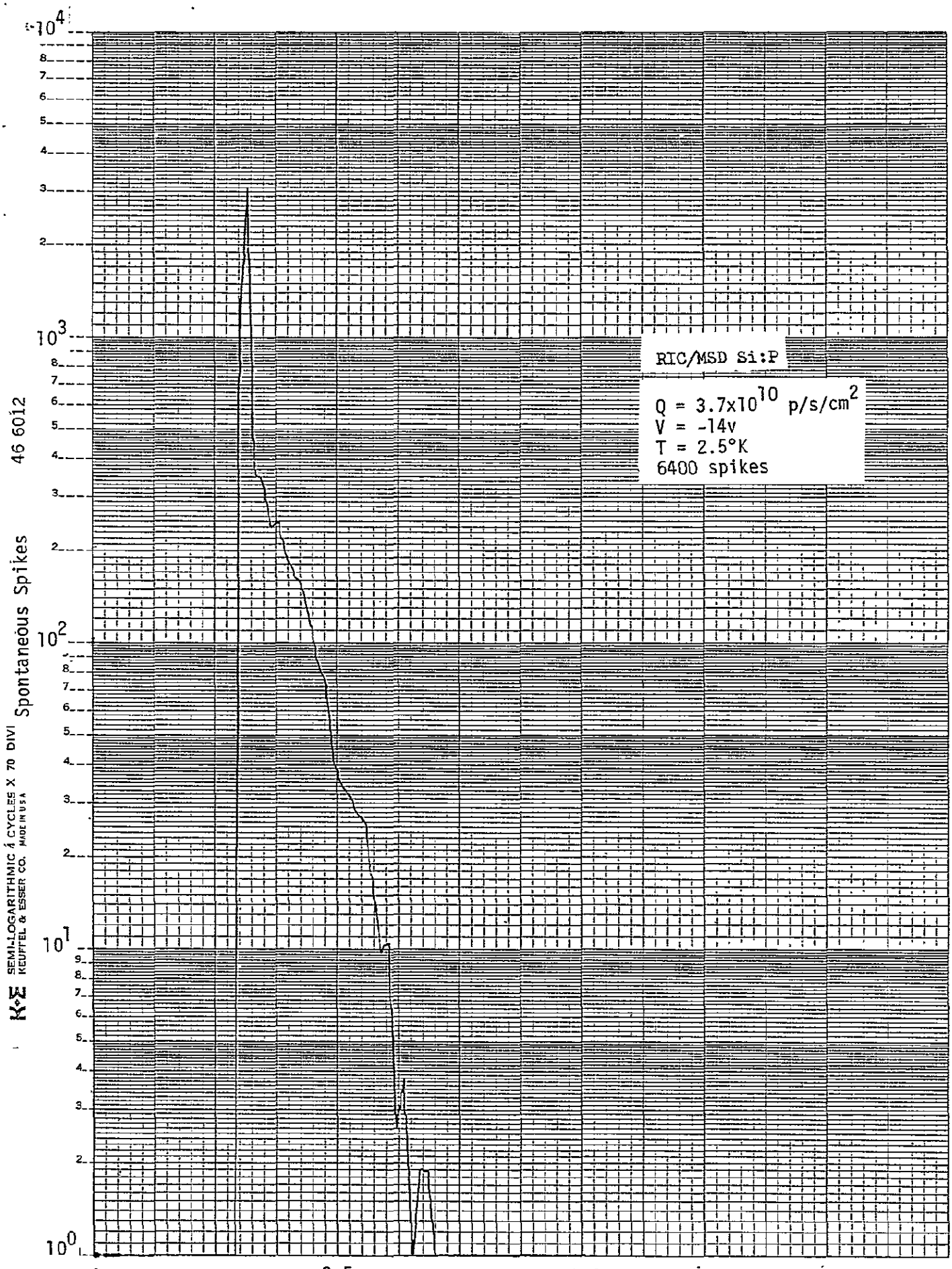

RIC/MSD Si:P
Q = 3.7x10^10 p/s/cm^2
V = -14v
T = 2.5°K
6400 spikes
Spontaneous Spikes
46 6012
K+E SEMI-LOGARITHMIC 4 CYCLES X 70 DIVI
KEUFFEL & ESSER CO. MADE IN USA
0
2.5
5.0
mV
PULSE AMPLITUDE

Figure 26

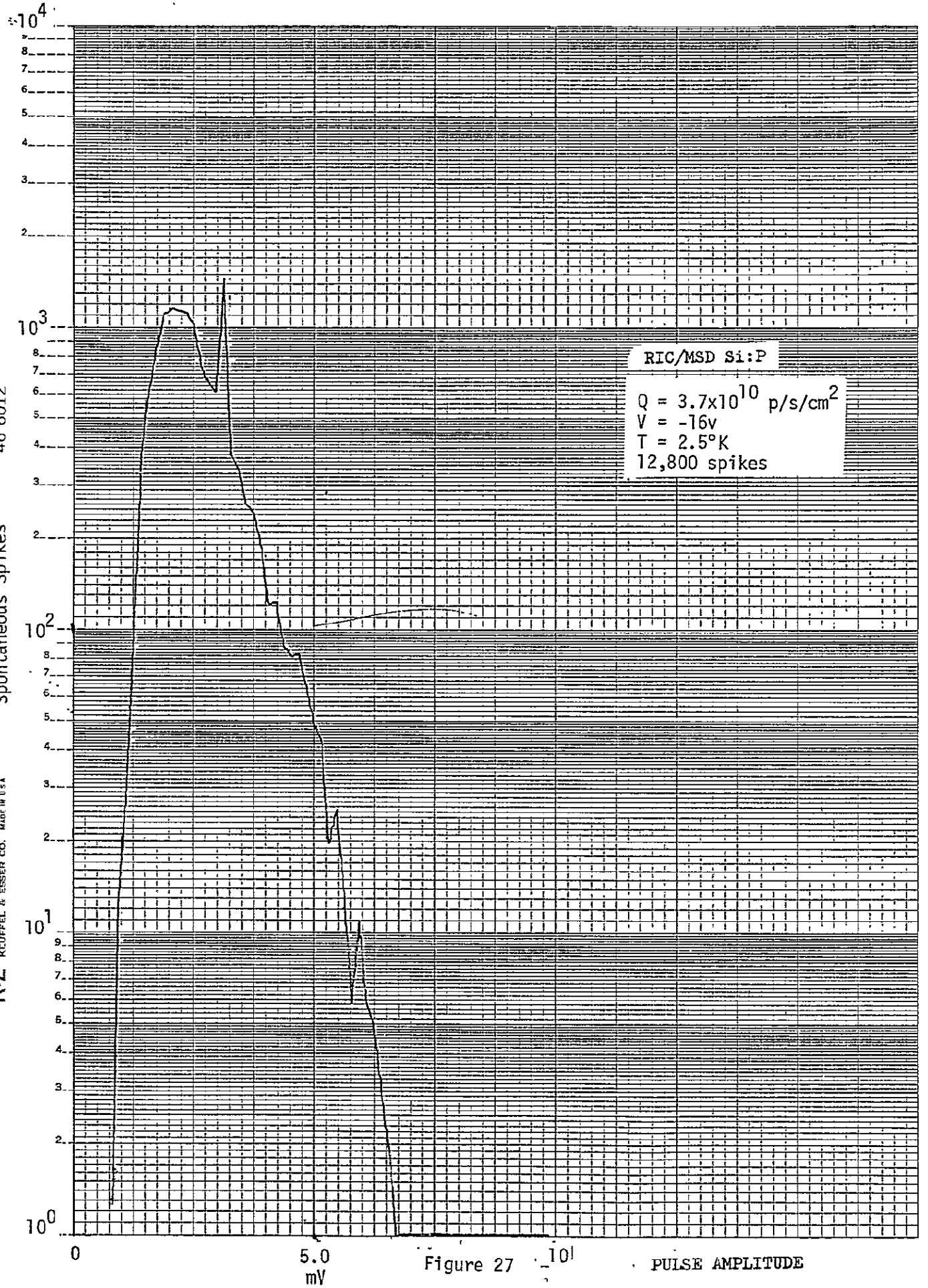

RIC/MSD Si:P
Q = 3.7x10^10 p/s/cm^2
V = -16v
T = 2.5°K
12,800 spikes
Spontaneous Spikes
PULSE AMPLITUDE
5.0 mV
46 6012
SEMI-LOGARITHMIC 4 CYCLES X 70 DIVI
KEUFFEL & ESSER CO. MADE IN U.S.A.

Figure 27

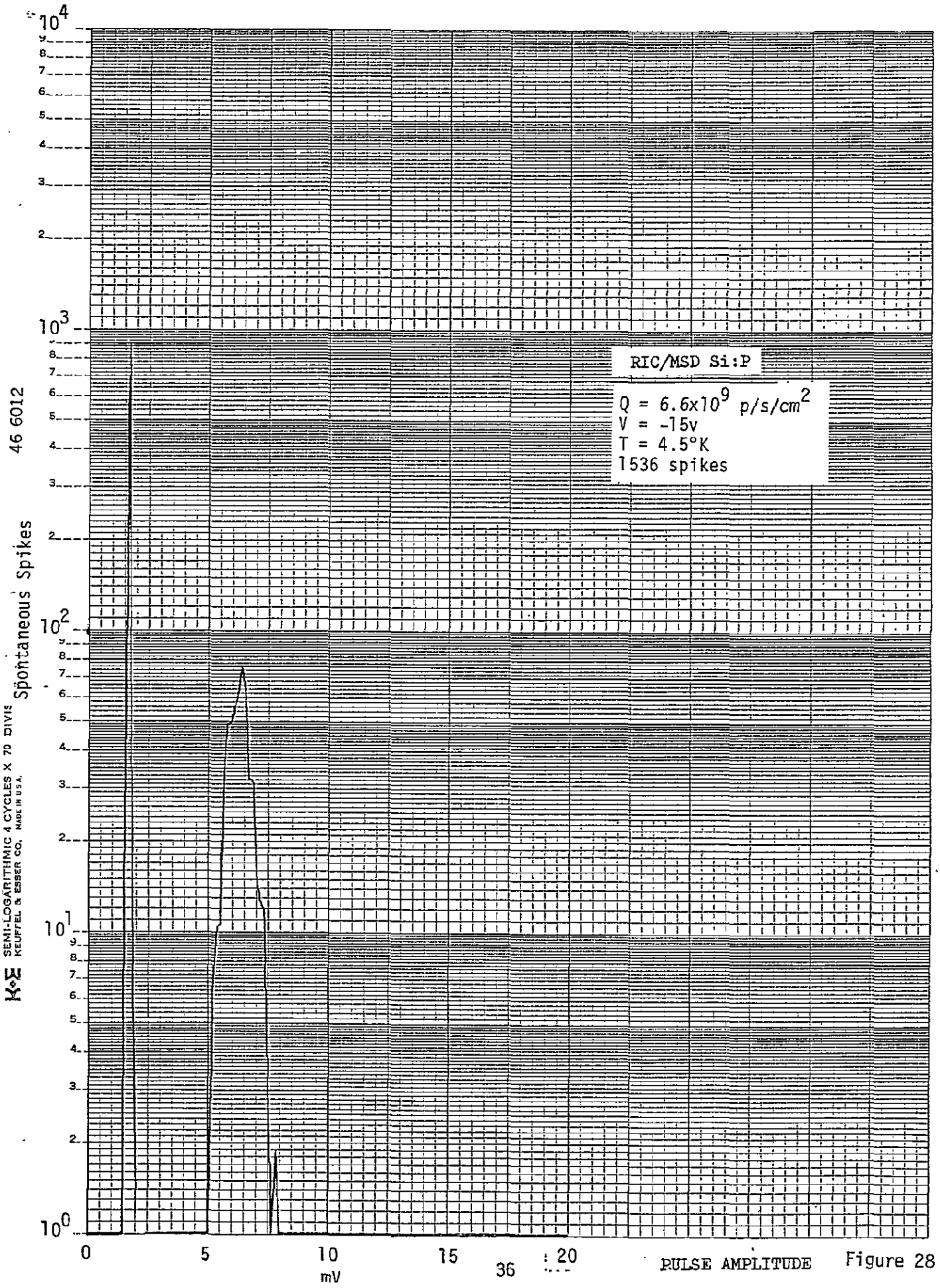
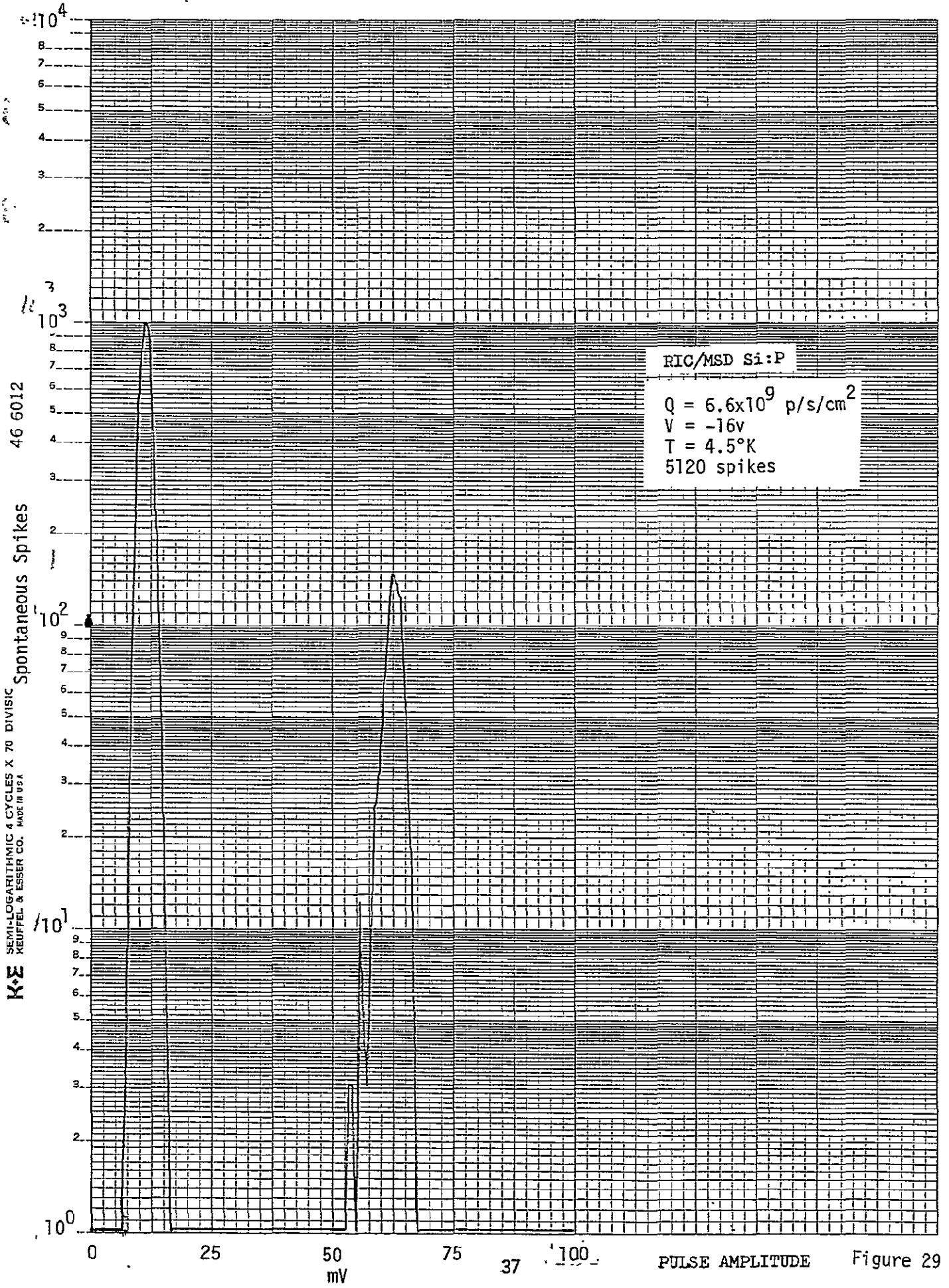

RIC/MSD Si:P
Q = 6.6x10^9 p/s/cm^2
V = -15v
T = 4.5°K
1536 spikes
Spontaneous Spikes
46 6012
K+E SEMI-LOGARITHMIC 4 CYCLES X 70 DIVIS
KEUFFEL & ESSER CO. MADE IN U.S.A.
10^4
10^3
10^2
10^1
10^0
0
5
10
15
20
mV
PULSE AMPLITUDE

Figure 28



PULSE AMPLITUDE

Figure 29

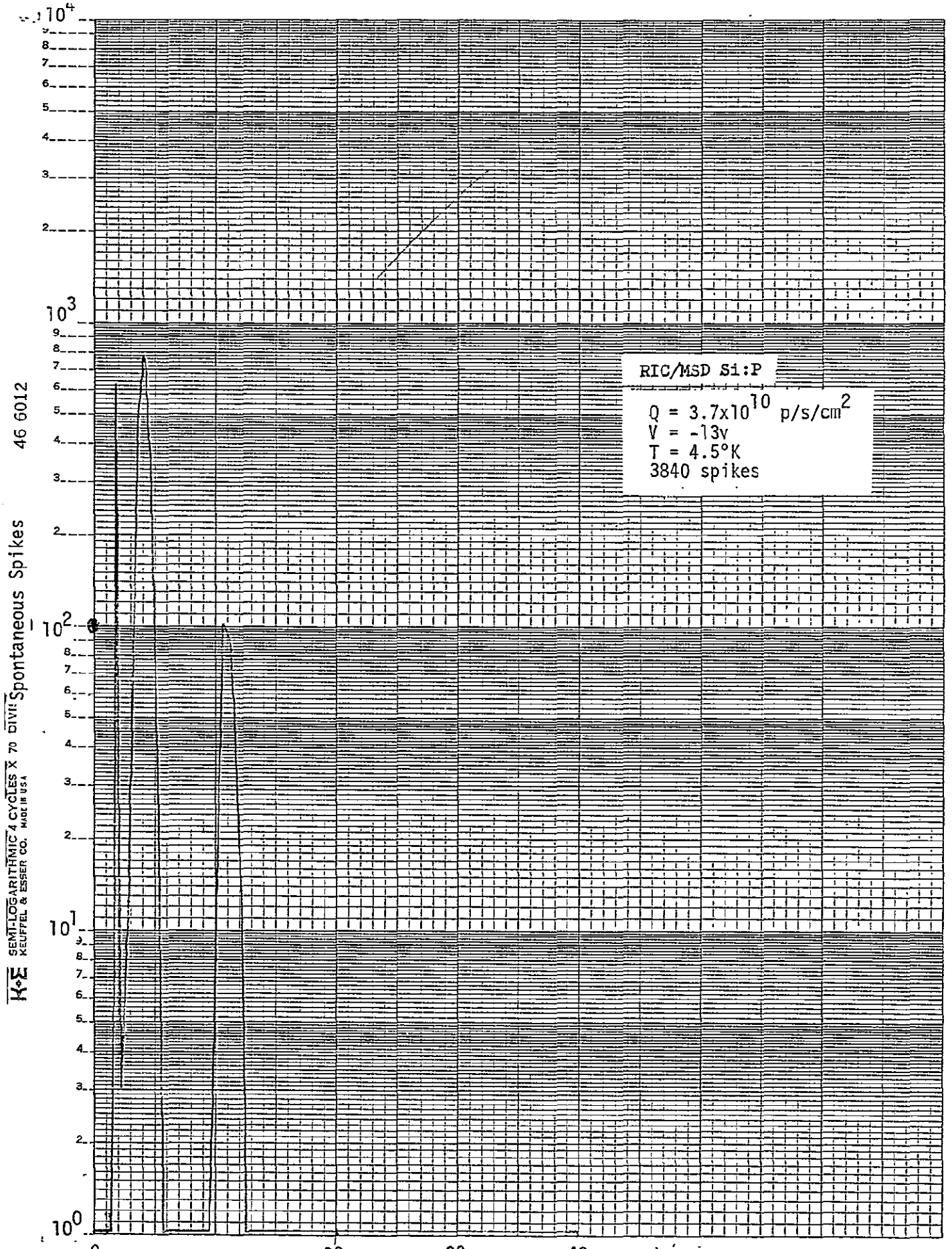

RIC/MSD Si:P
Q = 3.7x10^10 p/s/cm^2
V = -13v
T = 4.5°K
3840 spikes
Spontaneous Spikes
46 6012
K+E SEMI-LOGARITHMIC 4 CYCLES X 70 DIVI
KEUFFEL & ESSER CO. MADE IN USA
10^4
10^3
10^2
10^1
10^0
0
10
20
30
40
mV
PULSE AMPLITUDE

Figure 30

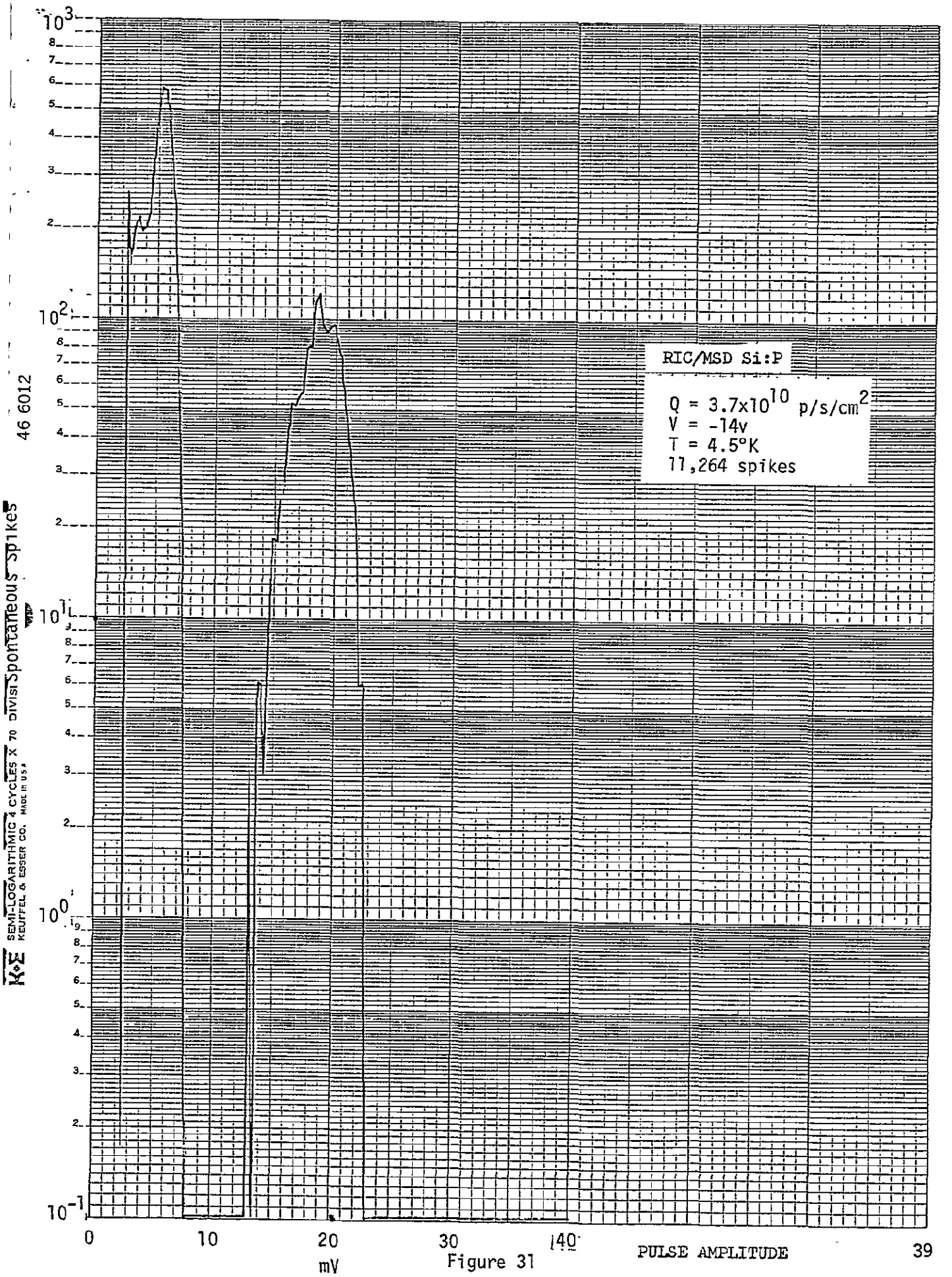

RIC/MSD Si:P
Q = 3.7x10^10 p/s/cm^2
V = -14v
T = 4.5°K
11,264 spikes
Spontaneous Spikes
PULSE AMPLITUDE
mV
0
10
20
30
40
46 6012
K+E SEMI-LOGARITHMIC 4 CYCLES X 70 DIVISIONS KEUFFEL & ESSER CO. MADE IN U.S.A.

Figure 31

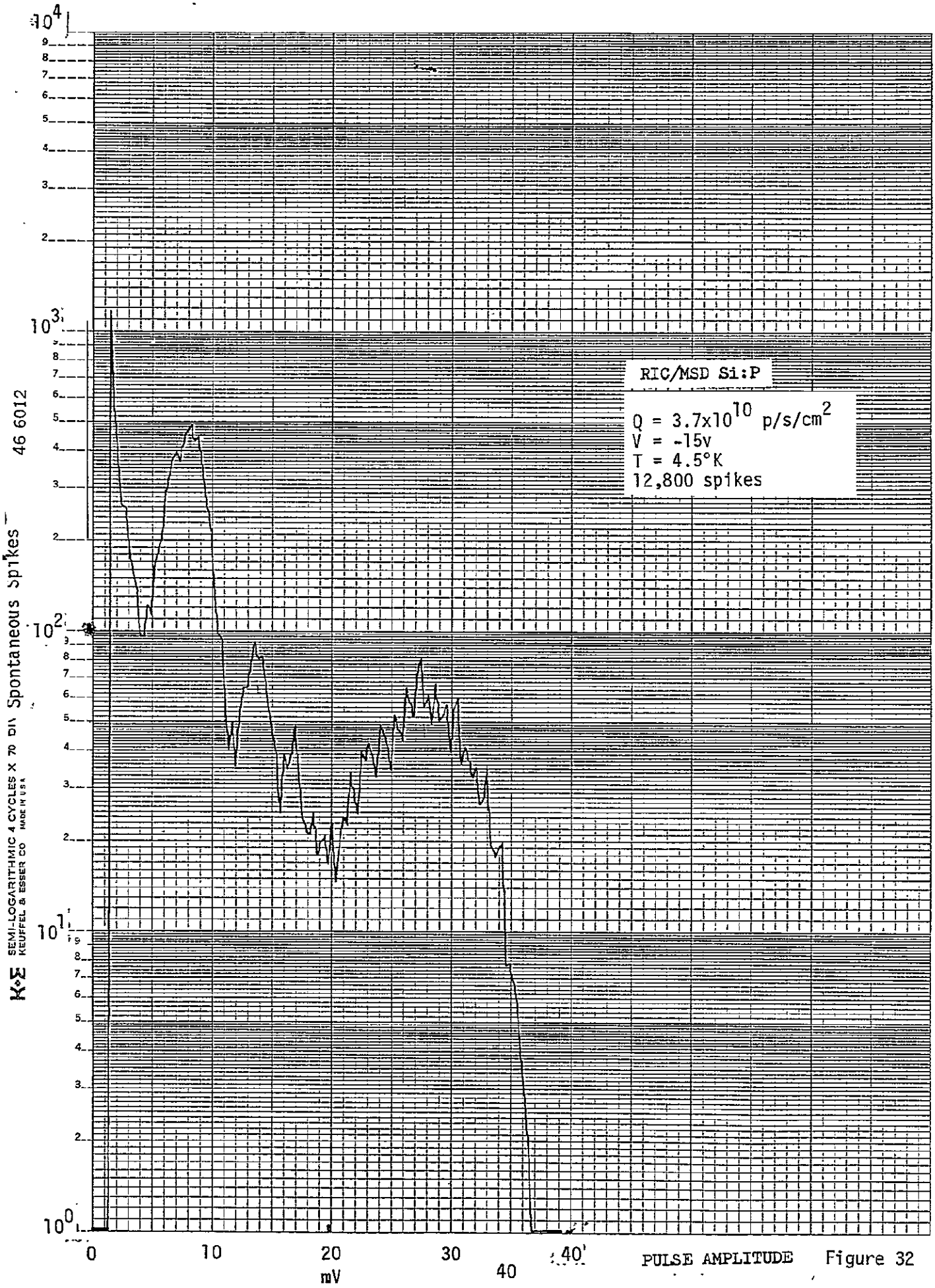

RIC/MSD Si:P
Q = 3.7x10^10 p/s/cm^2
V = -15v
T = 4.5°K
12,800 spikes
Spontaneous spikes
46 6012
K•E SEMI-LOGARITHMIC 4 CYCLES X 70 DIV
KEUFFEL & ESSER CO MADE IN USA
10^4
10^3
10^2
10^1
10^0
0
10
20
30
40
mV
40
PULSE AMPLITUDE

Figure 32

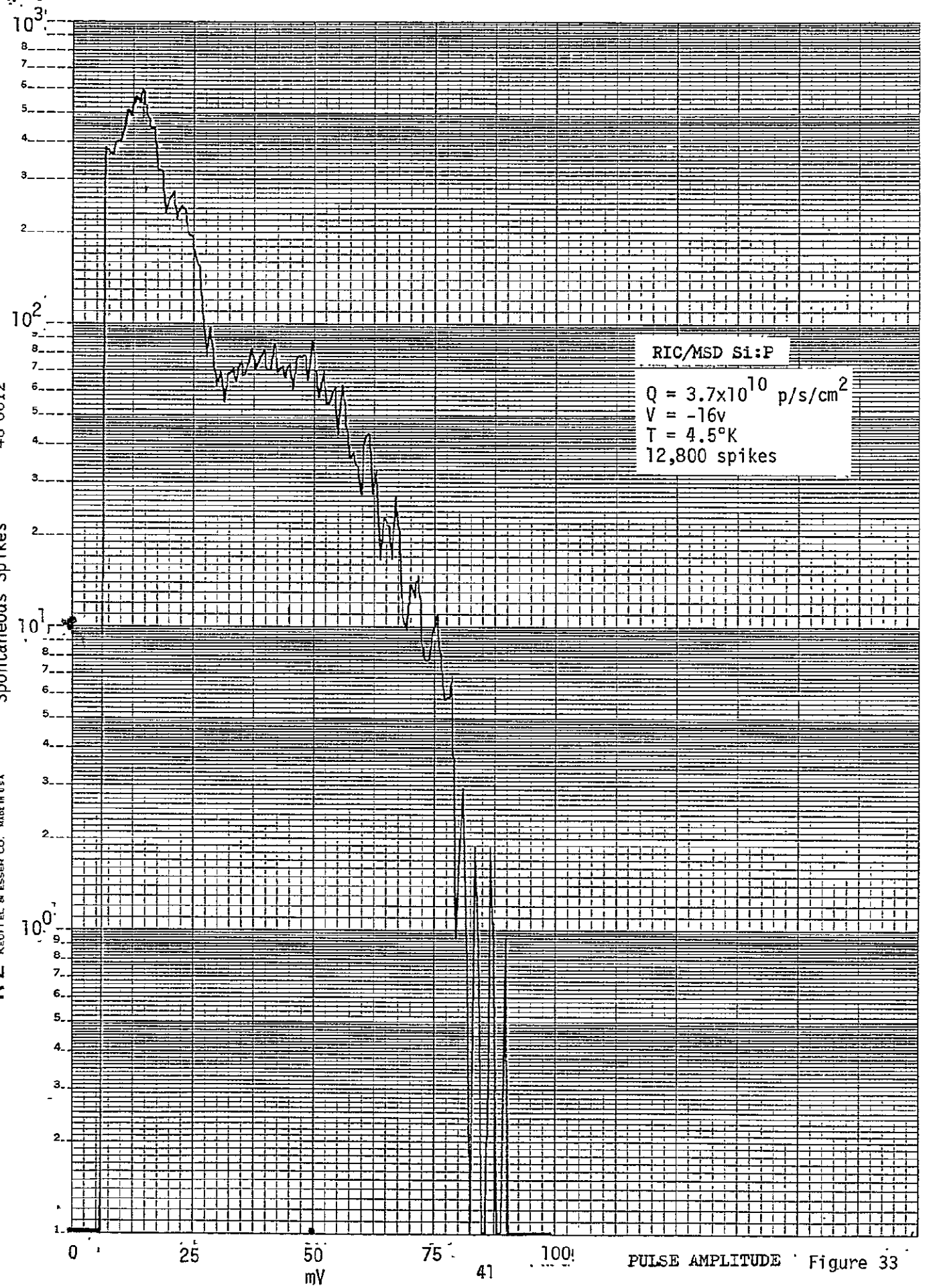

RIC/MSD Si:P
Q = 3.7x10^10 p/s/cm^2
V = -16v
T = 4.5°K
12,800 spikes
Spontaneous Spikes
46 6012
KE SEMI-LOGARITHMIC 4 CYCLES X 70 DIVI
KEUFFEL & ESSER CO. MADE IN U.S.A.
0
25
50
75
100
mV
PULSE AMPLITUDE

Figure 33

5.1.3. Gamma Event Pulse Height Distribution

This Section presents several graphs (Figs. 34-40) showing the amplitude distribution of pulses produced by Cobalt 60-gammas. Data was obtained under a zilch optical background to minimize the number of spontaneous noise spike events. Measurements were made at temperatures of 2.5K and 4.5K and at several bias values using a TIA. The resulting distributions appear to be quite gaussian and resemble the distributions of spontaneous spikes at 2.5K except that the pulse amplitudes are larger.

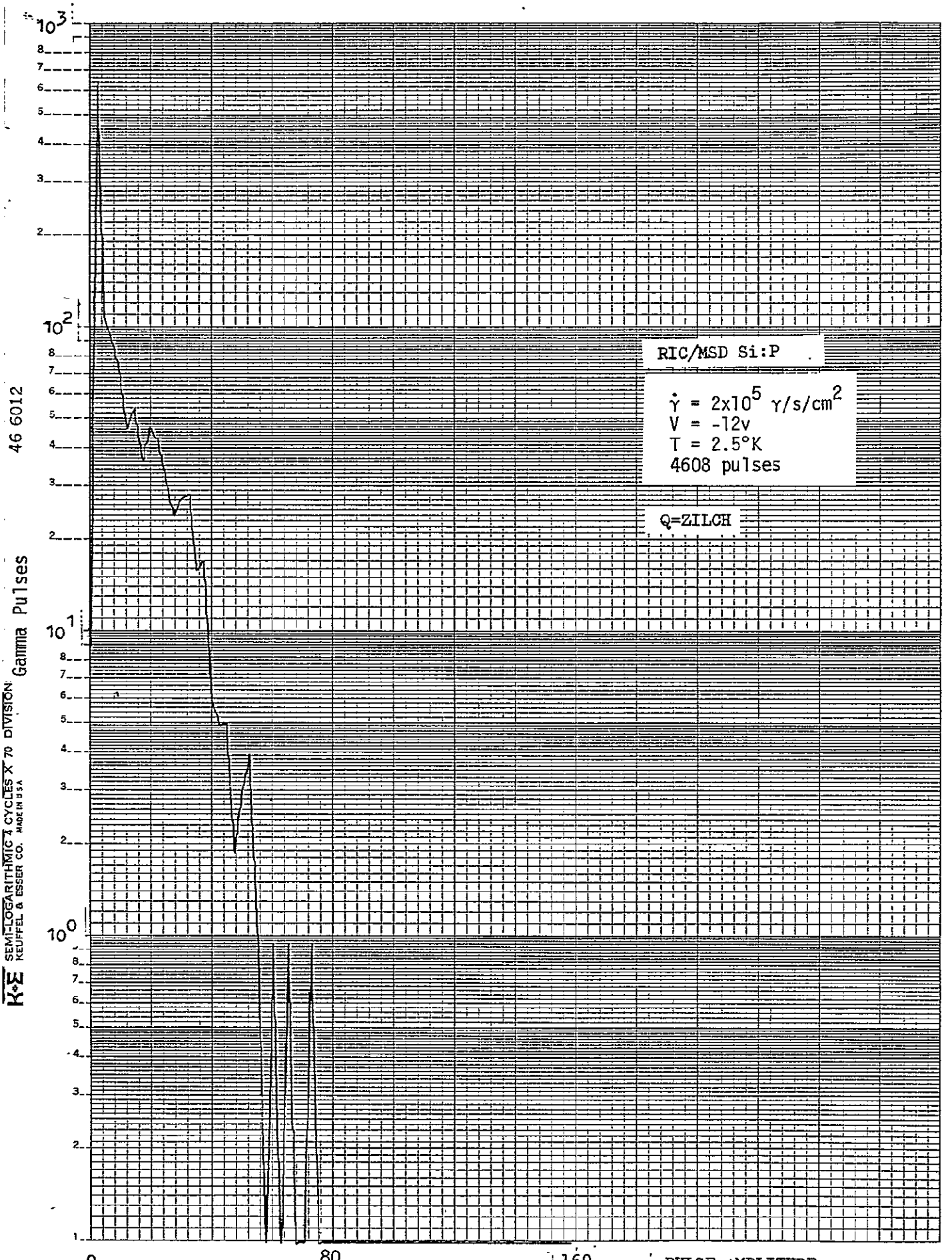

RIC/MSD Si:P
$\dot{\gamma}$ = 2x10^5 γ/s/cm^2
V = -12v
T = 2.5°K
4608 pulses
Q=ZILCH
Gamma Pulses
PULSE AMPLITUDE
0
80
160
mV
46 6012
SEMI-LOGARITHMIC 4 CYCLES X 70 DIVISION
KEUFFEL & ESSER CO. MADE IN U.S.A.

Figure 34

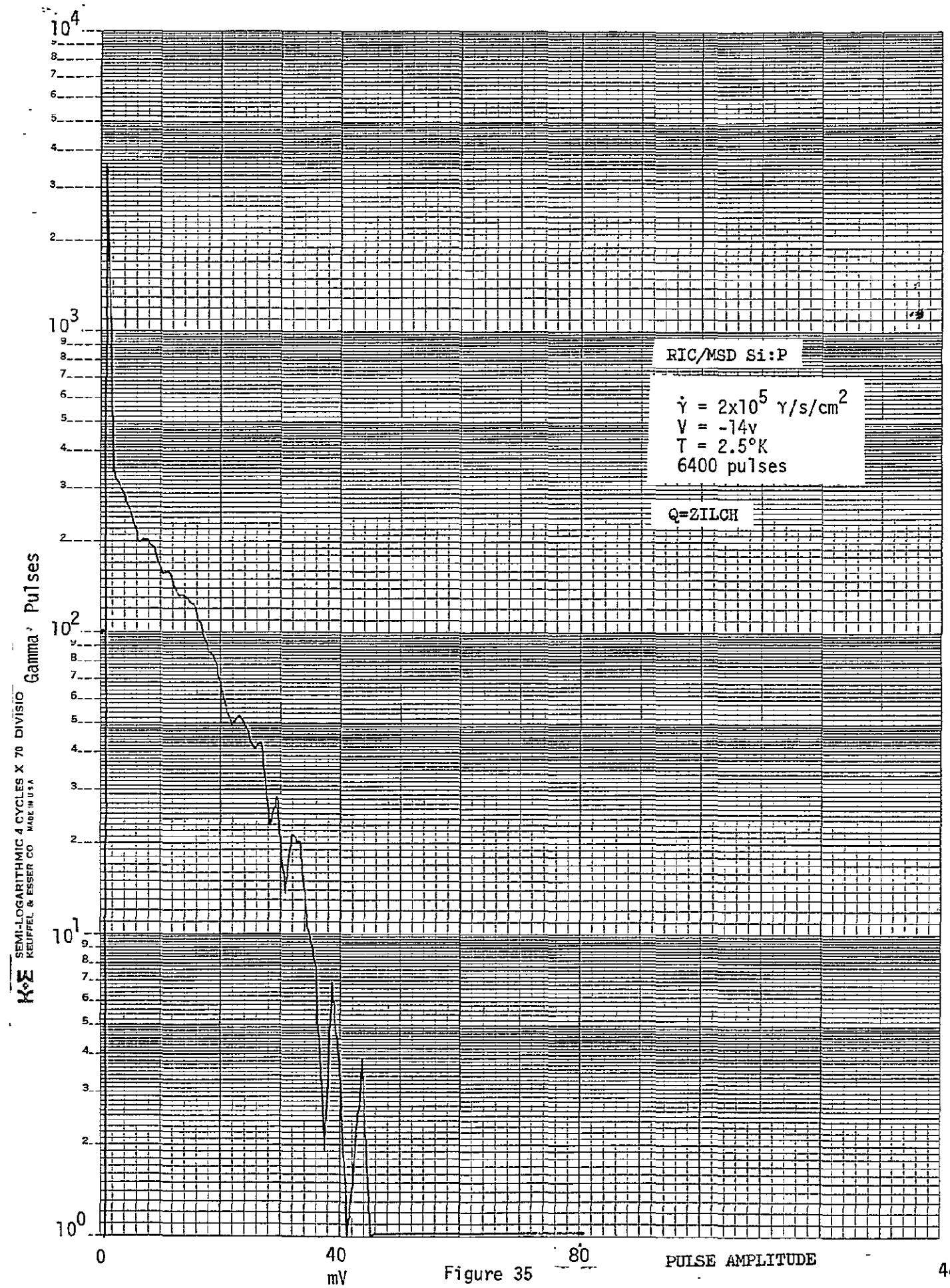

RIC/MSD Si:P
$\dot{\gamma}$ = 2x10^5 γ/s/cm^2
V = -14v
T = 2.5°K
6400 pulses
Q=ZILCH
Gamma' Pulses
PULSE AMPLITUDE
0
40
80
mV
SEMI-LOGARITHMIC 4 CYCLES X 70 DIVISIO
KEUFFEL & ESSER CO MADE IN U.S.A.

Figure 35

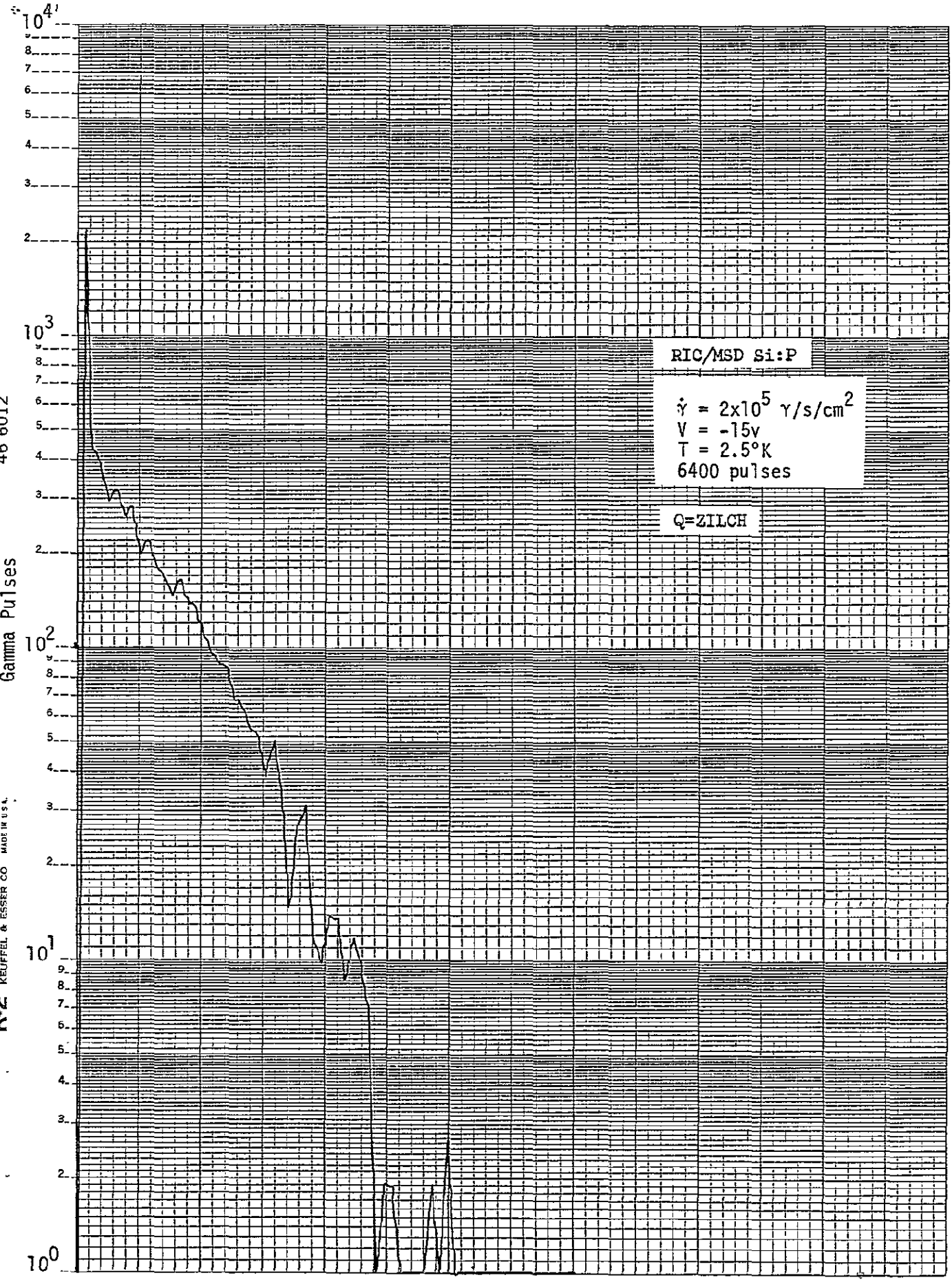

RIC/MSD Si:P
$\dot{\gamma}$ = 2x10^5 γ/s/cm^2
V = -15v
T = 2.5°K
6400 pulses
Q=ZILCH
Gamma Pulses
PULSE AMPLITUDE
0
40
80
mV
46 6012
SEMI-LOGARITHMIC 4 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO MADE IN U.S.A.

Figure 36

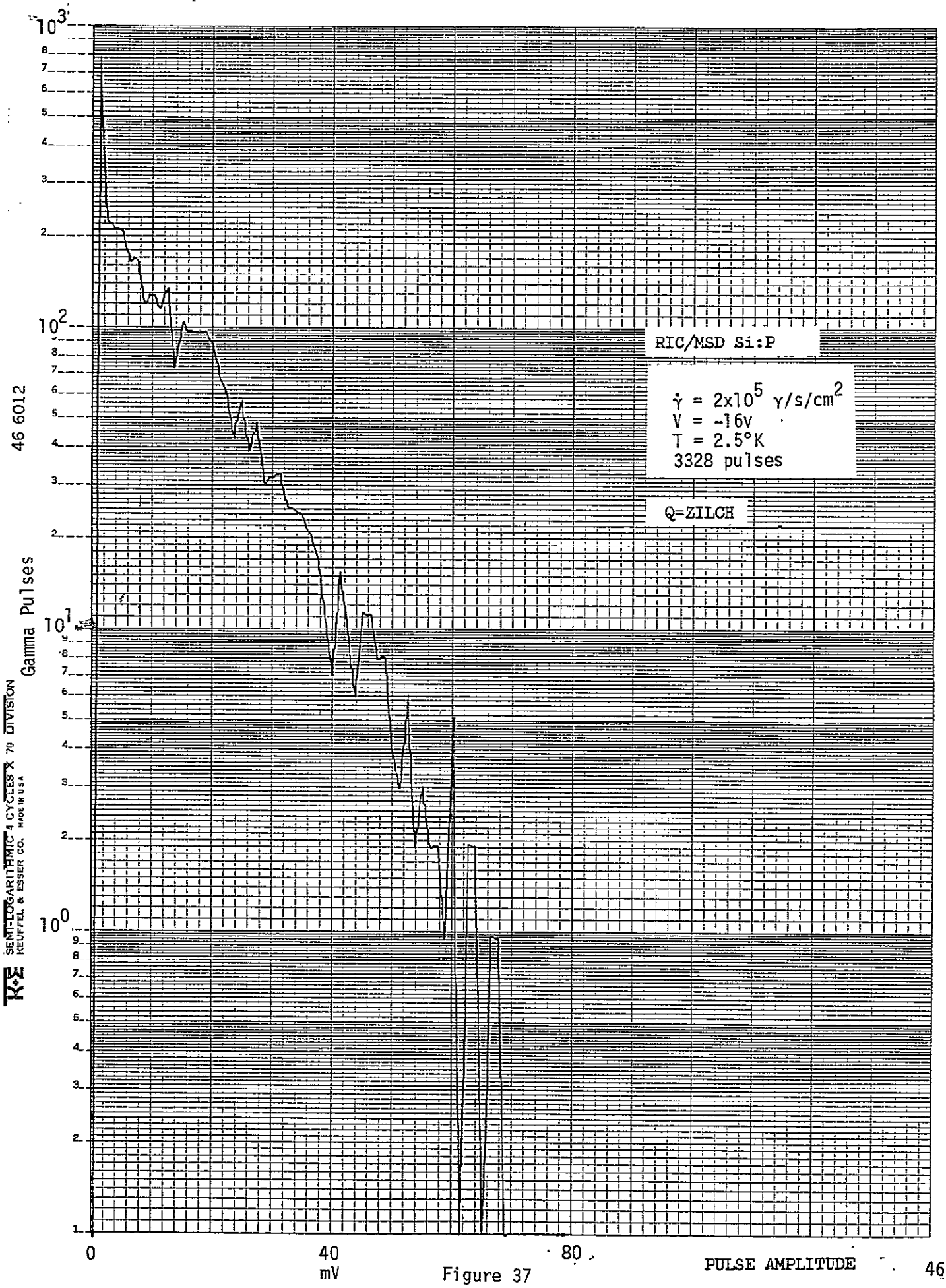

RIC/MSD Si:P
$\dot{\gamma}$ = 2x10^5 γ/s/cm^2
V = -16v
T = 2.5°K
3328 pulses
Q=ZILCH
Gamma Pulses
PULSE AMPLITUDE
mV
0
40
80
46 6012
SEMI-LOGARITHMIC 4 CYCLES X 70 DIVISION
KEUFFEL & ESSER CO. MADE IN U.S.A.

Figure 37

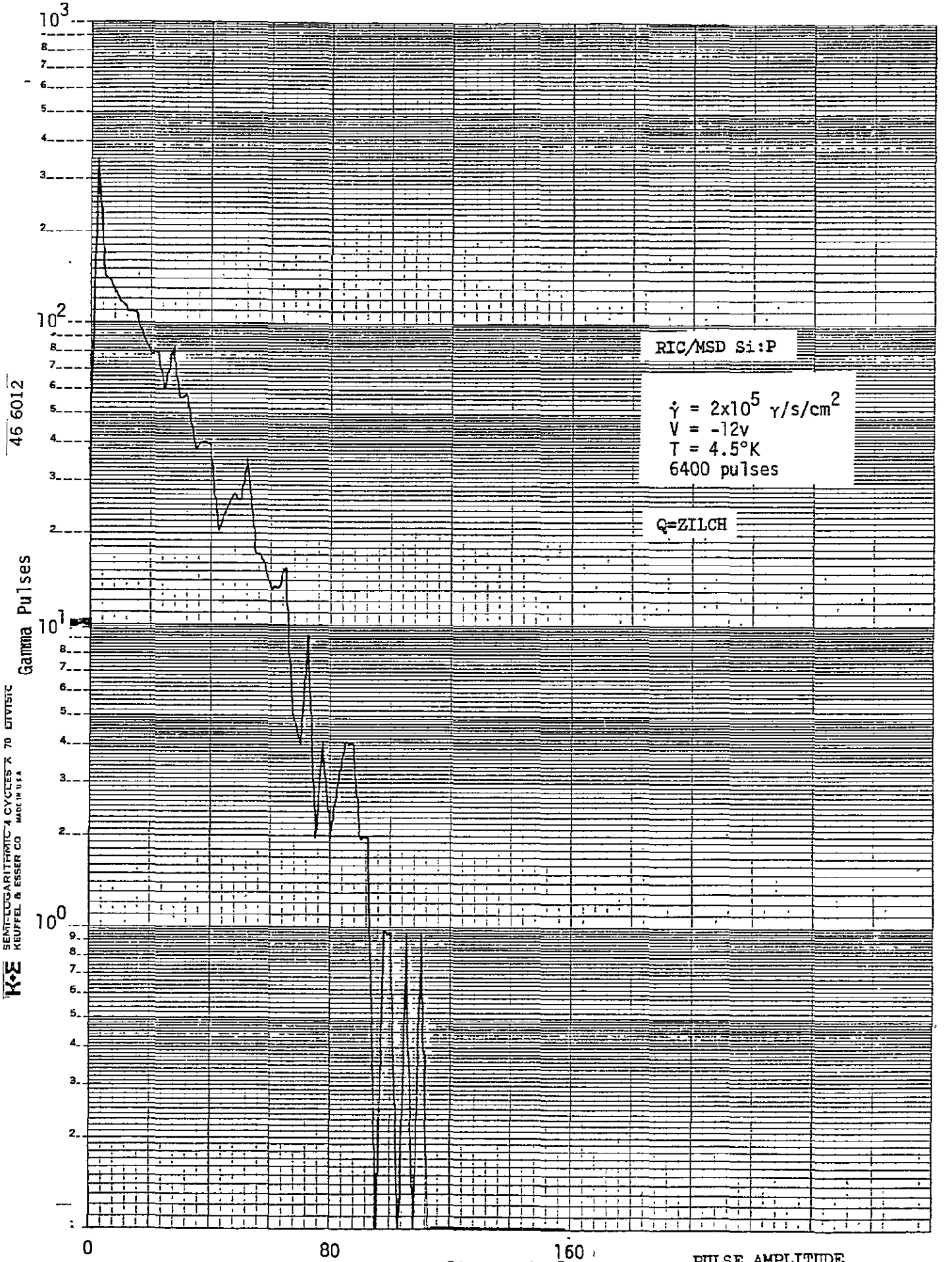

RIC/MSD Si:P
$\dot{\gamma}$ = 2x10^5 γ/s/cm^2
V = -12v
T = 4.5°K
6400 pulses
Q=ZILCH
Gamma Pulses
PULSE AMPLITUDE
0
80
160
mV
46 6012
SEMI-LOGARITHMIC 4 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO MADE IN U.S.A.

Figure 38

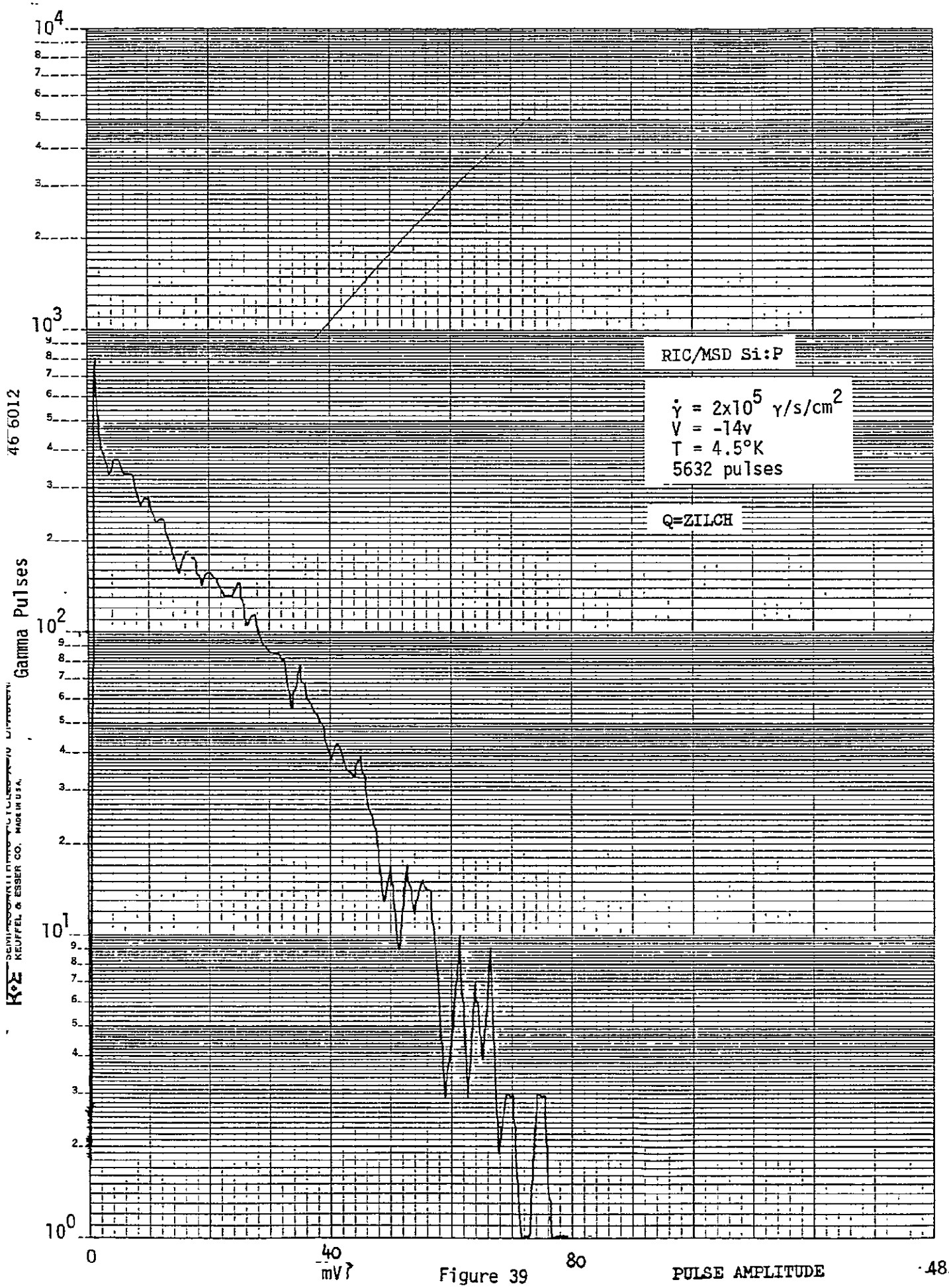

RIC/MSD Si:P
$\dot{\gamma}$ = 2x10^5 γ/s/cm^2
V = -14v
T = 4.5°K
5632 pulses
Q=ZILCH
Gamma Pulses
PULSE AMPLITUDE
0
40
80
mV?
46 6012
KEUFFEL & ESSER CO. MADE IN U.S.A.

Figure 39

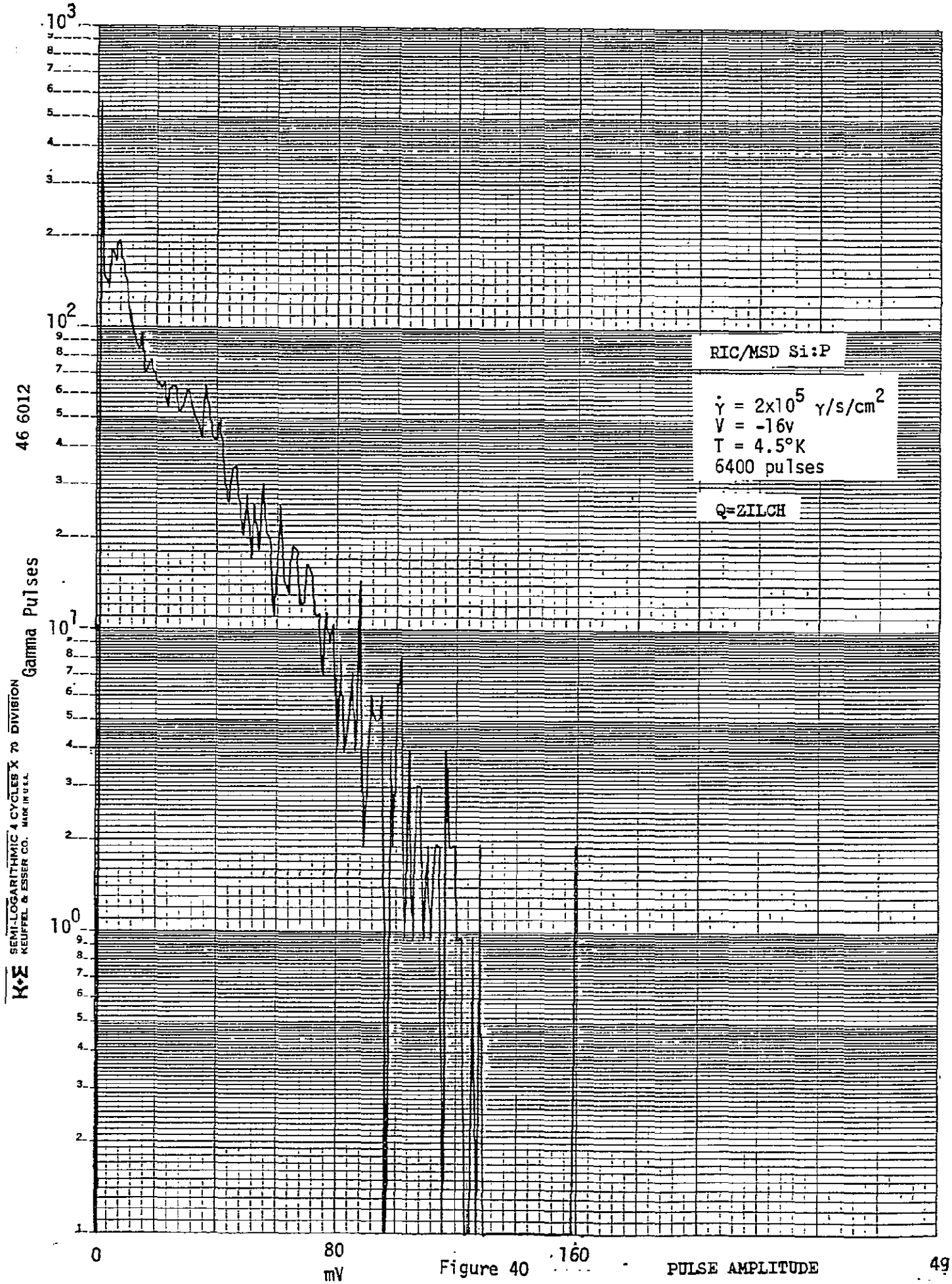

RIC/MSD Si:P
$\dot{\gamma}$ = 2x10^5 γ/s/cm^2
V = -16v
T = 4.5°K
6400 pulses
Q=ZILCH
Gamma Pulses
SEMI-LOGARITHMIC 4 CYCLES X 70 DIVISION
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 6012
0
80
160
mV
PULSE AMPLITUDE

Figure 40

5.1.4. Spike Event Pulse Shapes

Figures 41 and 42 show the time dependence of spontaneous noise spikes at 2.5K and 4.5K. An average of 100 pulses was used to increase the signal to noise ratio. These spikes are characterized by an initial fast rise (not shown), an initial fast decay with ringing (caused by electronics), and a slow decay. The final slow decay corresponds to the RC time constant of the feedback resistor used in the TIA. The decay times are about 1.9 ms at 2.5K and 0.5 ms at 4.5K which correspond to the value of the feedback resistor and its shunt capacitance of about 0.5μμf. Figure 43 shows similar data for gamma-induced spikes at a zilch optical background and at 4.5K. Note that the time dependence of the gamma-induced spikes is identical to that of the spontaneous noise spikes.

K-E SEMI-LOGARITHMIC 2 CYCLES X 200 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

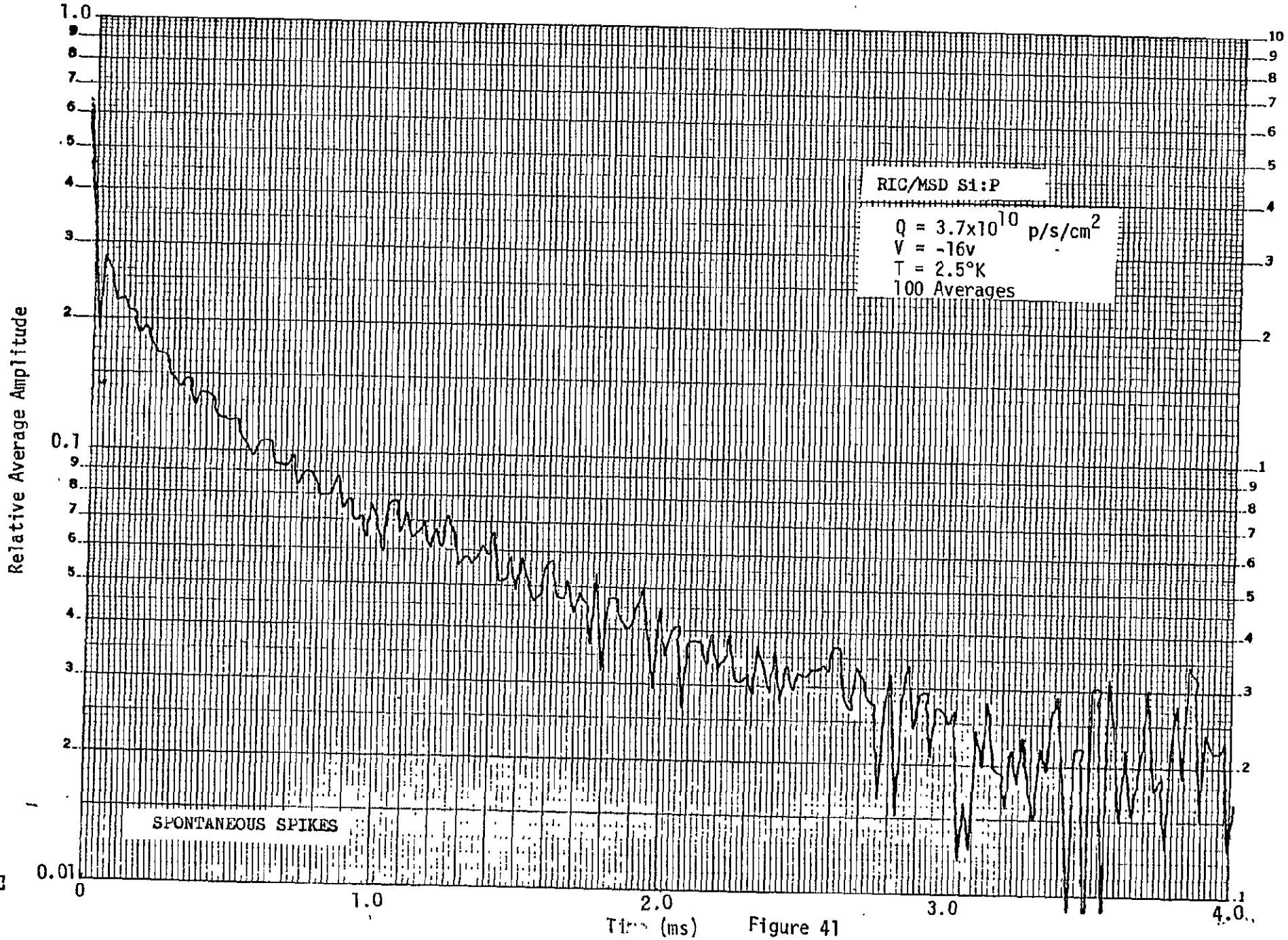


Figure 41

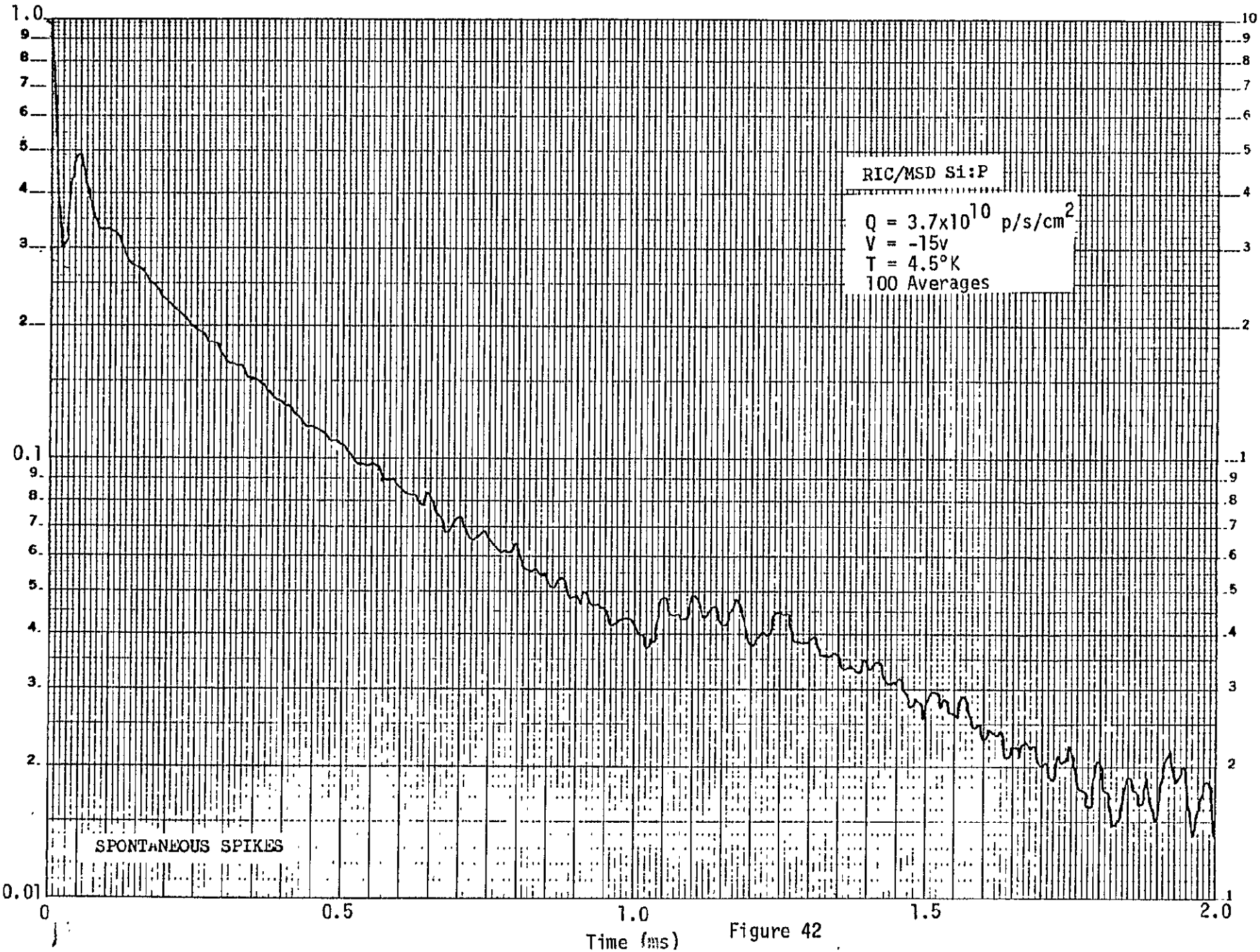

RIC/MSD Si:P
Q = 3.7x10^10 p/s/cm^2
V = -15v
T = 4.5°K
100 Averages
SPONTANEOUS SPIKES
Relative Average Amplitude
Time (ms)
1.0
0.1
0.01
0
0.5
1.0
1.5
2.0

Figure 42

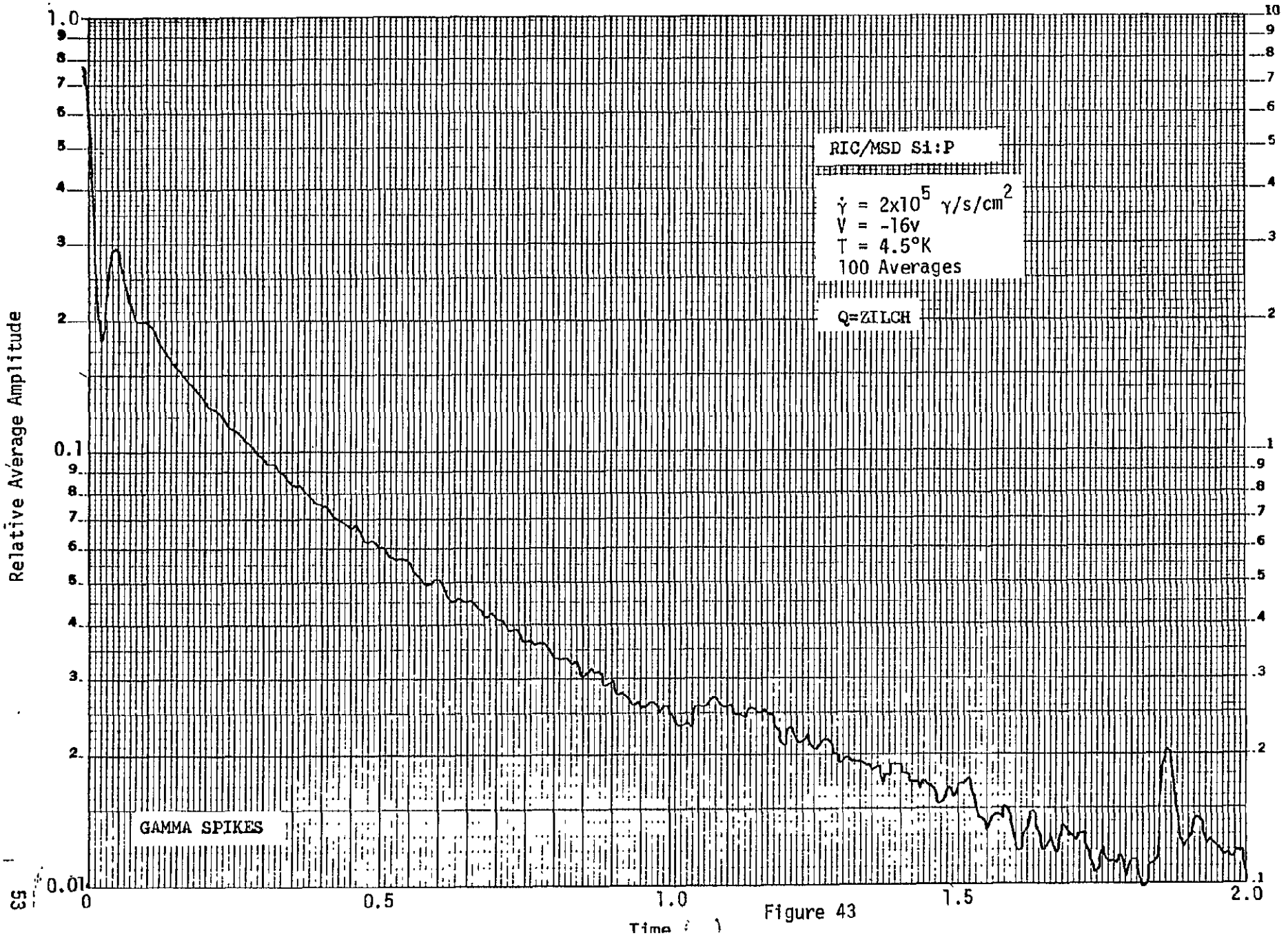

RIC/MSD Si:P
$\dot{\gamma}$ = 2x10^5 γ/s/cm^2
V = -16v
T = 4.5°K
100 Averages
Q=ZILCH
GAMMA SPIKES
Relative Average Amplitude
Time
1.0
0.1
0.01
0
0.5
1.0
1.5
2.0

Figure 43

5.1.5. Software Circumvention of Spikes

A computer program was written to remove spikes from time domain data to see how well the resulting noise spectra would match a noise spectra measured without spikes. This program used a relatively simple algorithm to perform the spike removal. It started at the beginning of the time domain data (t = 0) and computed the average value of the data from t = 0 up to each consecutive data point. If the value of any data point exceeded a preselected value (somewhat above the peak-to-peak detector noise level), the current average was substituted for that data point and a new current average computed using the substituted value (average remained the same). This process continued until the entire time domain window had been filled. The results of this spike removal technique are shown in Figs. 44 and 45 for time windows of 10 and 100 sec. where the data with and without spikes are shown. Note the relative uniformity in both time spacing and in the amplitudes of the larger pulses.

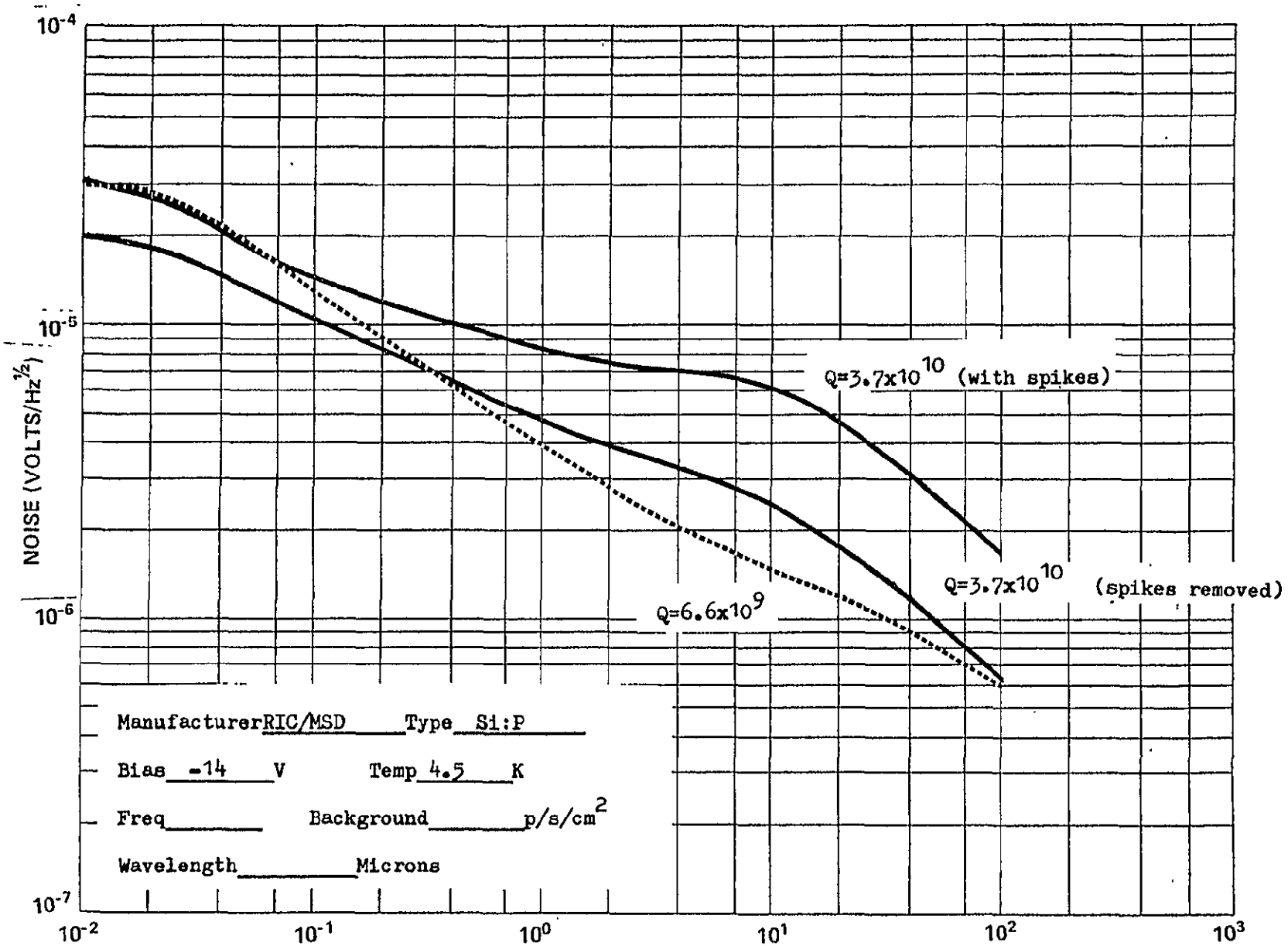
These data were then used to calculate the noise spectra for both cases and the data are shown in Fig. 46. A source follower configuration was used for these data. Note the decrease in noise for the "deglitched" data. For comparison purposes, the noise spectra at a lower background is also shown. At this background the number of spontaneous noise spikes was greatly reduced. The agreement between the "deglitched" noise at 3.7×10^{10} p/s/cm^2 and the noise at 6.6×10^{9} p/s/cm^2 is fairly good except between 1 and 50 Hz. The additional noise at the higher frequencies may be due to background noise (which remains after the apikes are removed) or due to small amplitude spikes which were not removed by this technique.

OUTPUT (50 μV/IN)
Q=3.7x10^10 (spikes removed)
RIC/MSD Si:P
T = 4.5K
V = -14V
OUTPUT (200 μV/IN)
Q=3.7x10^10 (with spikes)
150 Hz BANDWITH
TIME (1 SEC/IN)

Figure 44

OUTPUT (100 μV/IN)
Q=3.7x10^10 (spikes removed)
RIC/MSD Si:P
T = 4.5K
V = -14V
OUTPUT (100 μV/IN)
Q=3.7x10^10 (with spikes)
15 Hz BANDWITH

Figure 45



NOISE SPECTRUM

Figure 46

5.2. RIC/MSD Si:As Hardware Circumvention of Gamma Spikes

The following data were obtained using an Aerojet Electrosystem Company (AESC) wideband feedback preamplifier (operating as a TIA) ac-coupled to a keyed-clamp circuit that was specifically designed for the suppression of gamma noise pulses.[1] Outputs for signal processing were available at the TIA as well as the keyed-clamp gate circuit. Provision was made for deactivating the gate so that a comparison of ungated (Blanking Off) and gated (Blanking On) signals could easily be made. The blanking time (gate width) could be varied from 24 microseconds to 400 microseconds; for these measurements, the blanking time was approximately 250-350 microseconds.

The Rockwell Si:As detector was used exclusively throughout these measurements. Noise measurements were made at a background of 5.6×10^9 p/s/cm^2. Bias on the detector was 5 volts and the temperature was 4.5K. Three Cobalt-60 gamma sources, 0.1, 1.0, and 10 millicurie, were used to establish gamma flux levels of 2×10^5, 2×10^6, and 2×10^7 gamma/sec/cm^2, respectively.

Figure 47 shows simultaneously-recorded data at the TIA output and the gate output with the blanking circuit operational. The effect of the blanking can be clearly seen. Figures 48 and 49 show the noise spectra at the TIA output for a clear environment and for the three gamma levels. Figure 50 shows the Noise spectra from the gate output but without blanking. These spectra are similar to those at the TIA output. Finally Fig. 51 shows the noise spectra from the gate output but with the blanking operational. The decrease in noise level is about a factor of 3 or 4.

---

1. C. M. Parry and J. B. Parkinson (AESC), Hardened Detector/Circuit Development (U), Volume I: AESC Final Report; DAHC 60-73-C-0059, September 1974 (SECRET).

It should be noted that the various adjustable parameters (peaking, lead compensation, pulse threshold, bandwidth, gate width, etc.) on the three circuit boards (preamplifier board, logic board, and gate board) in the AESC amplifier set, at the start of these measurements, to provide for the minimum distortion of the signal and noise output while using a minimum blanking time to suppress gamma pulses from the 1 millicurie gamma source. Once this optimum had been achieved, no further adjustments were made on the amplifier during the course of these measurements.

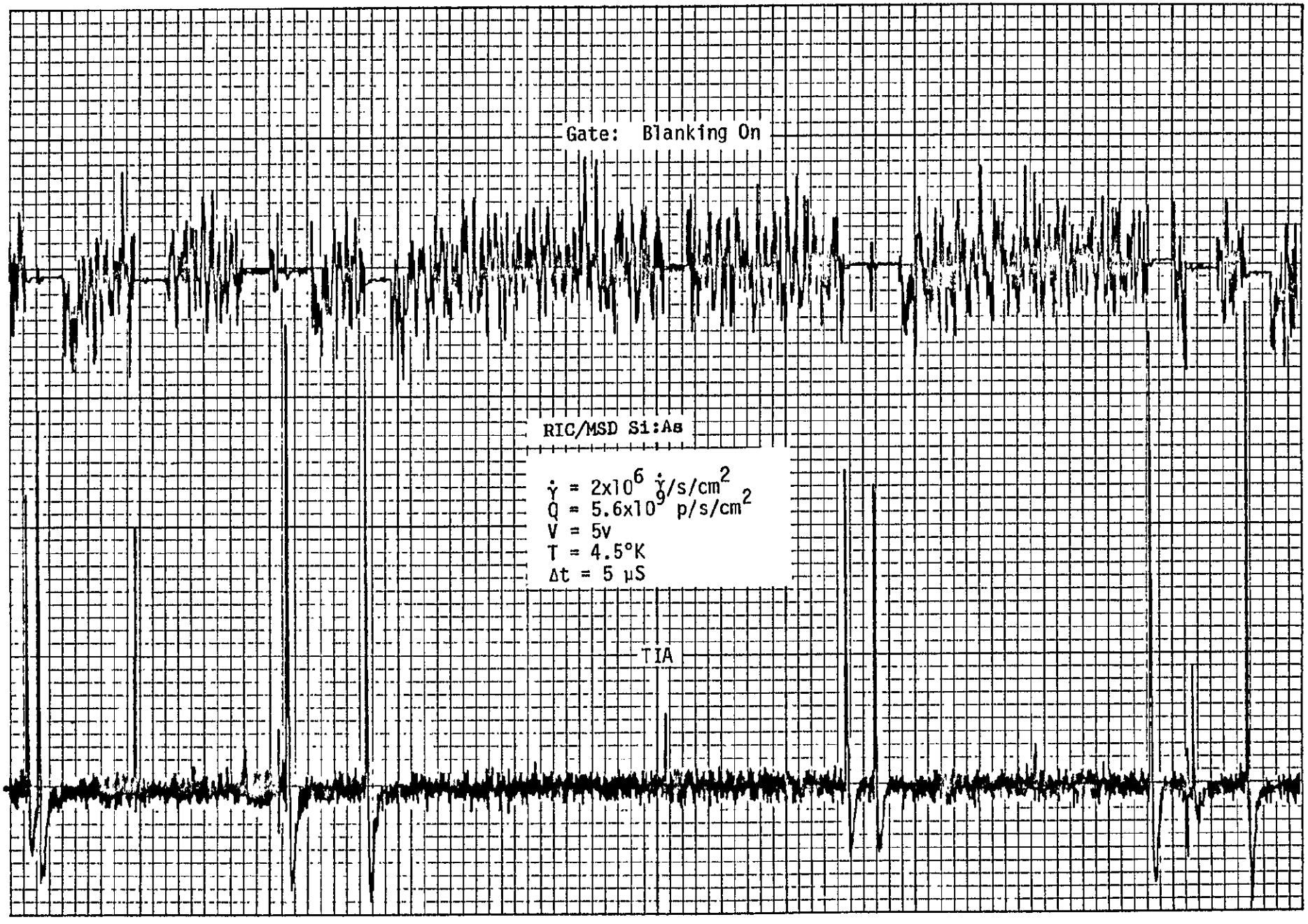

Gate: Blanking On
RIC/MSD Si:As
$\dot{\gamma}$ = 2x10^6 $\dot{\gamma}$/s/cm^2
Q = 5.6x10^9 p/s/cm^2
V = 5v
T = 4.5°K
Δt = 5 μS
TIA
0.1 v/in
2.0 v/in
Time (.05 ms/in)

Figure 47

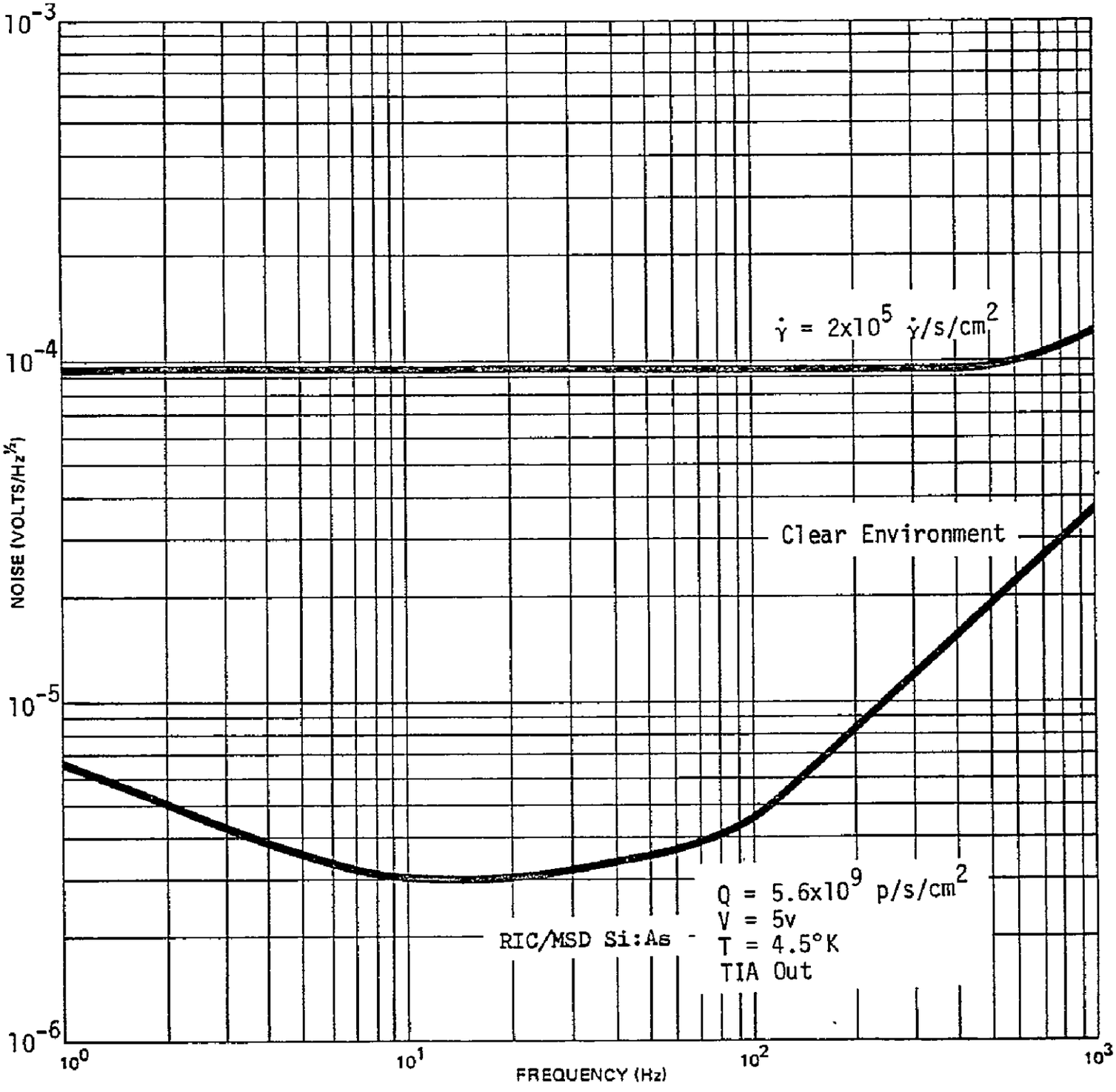

10^{-3}
10^{-4}
10^{-5}
10^{-6}
NOISE (VOLTS/Hz$^{1/2}$)
$\dot{\gamma}$ = 2x10^{5} $\dot{\gamma}$/s/cm^{2}
Clear Environment
Q = 5.6x10^{9} p/s/cm^{2}
V = 5v
T = 4.5°K
TIA Out
RIC/MSD Si:As
10^{0}
10^{1}
10^{2}
10^{3}
FREQUENCY (Hz)

Figure 48

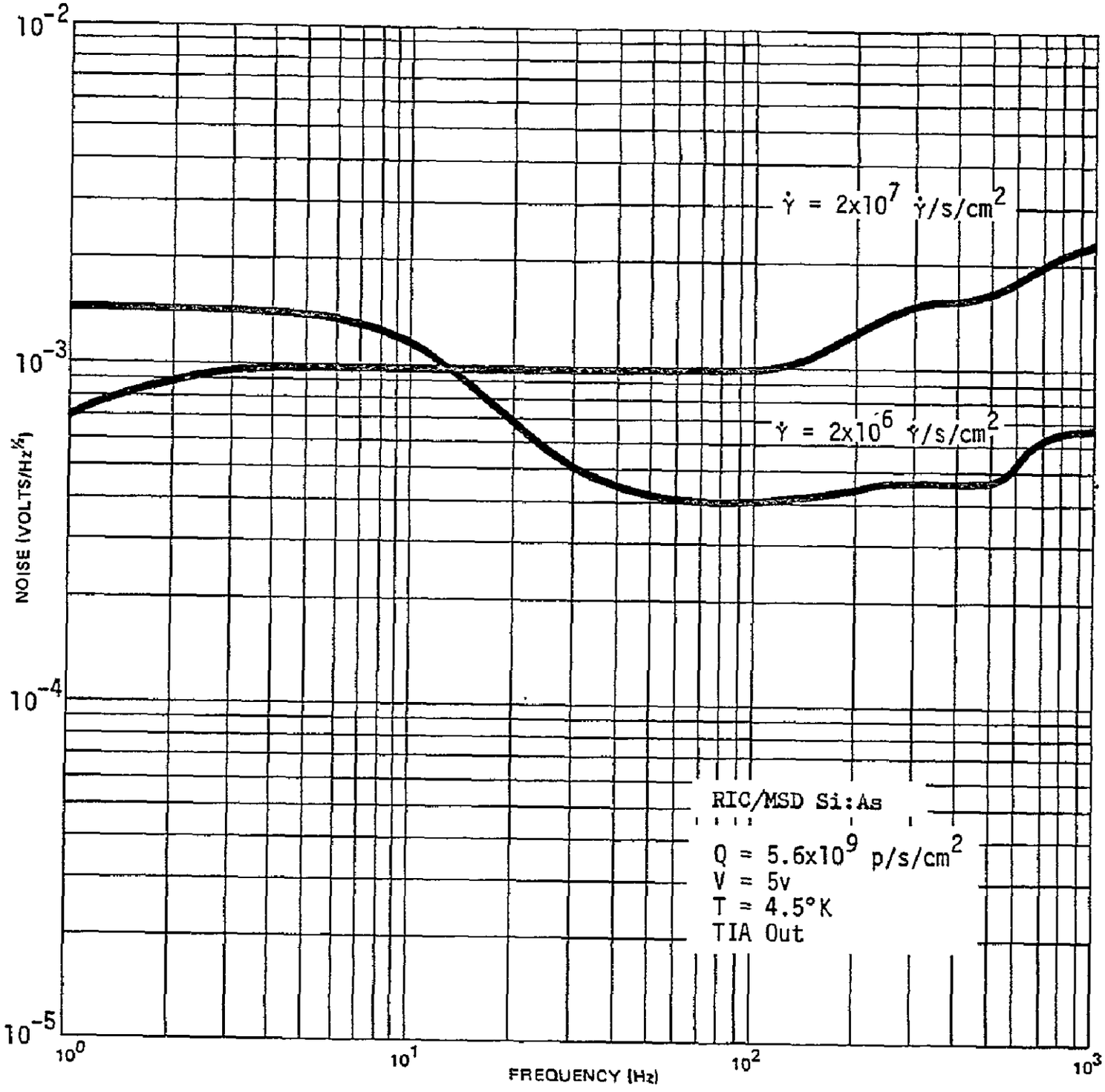

10^{-2}
10^{-3}
10^{-4}
10^{-5}
NOISE (VOLTS/Hz$^{1/2}$)
10^{0}
10^{1}
10^{2}
10^{3}
FREQUENCY (Hz)
$\dot{Y}$ = 2x10^{7} $\dot{Y}$/s/cm^{2}
$\dot{Y}$ = 2x10^{6} $\dot{Y}$/s/cm^{2}
RIC/MSD Si:As
Q = 5.6x10^{9} p/s/cm^{2}
V = 5v
T = 4.5°K
TIA Out

Figure 49

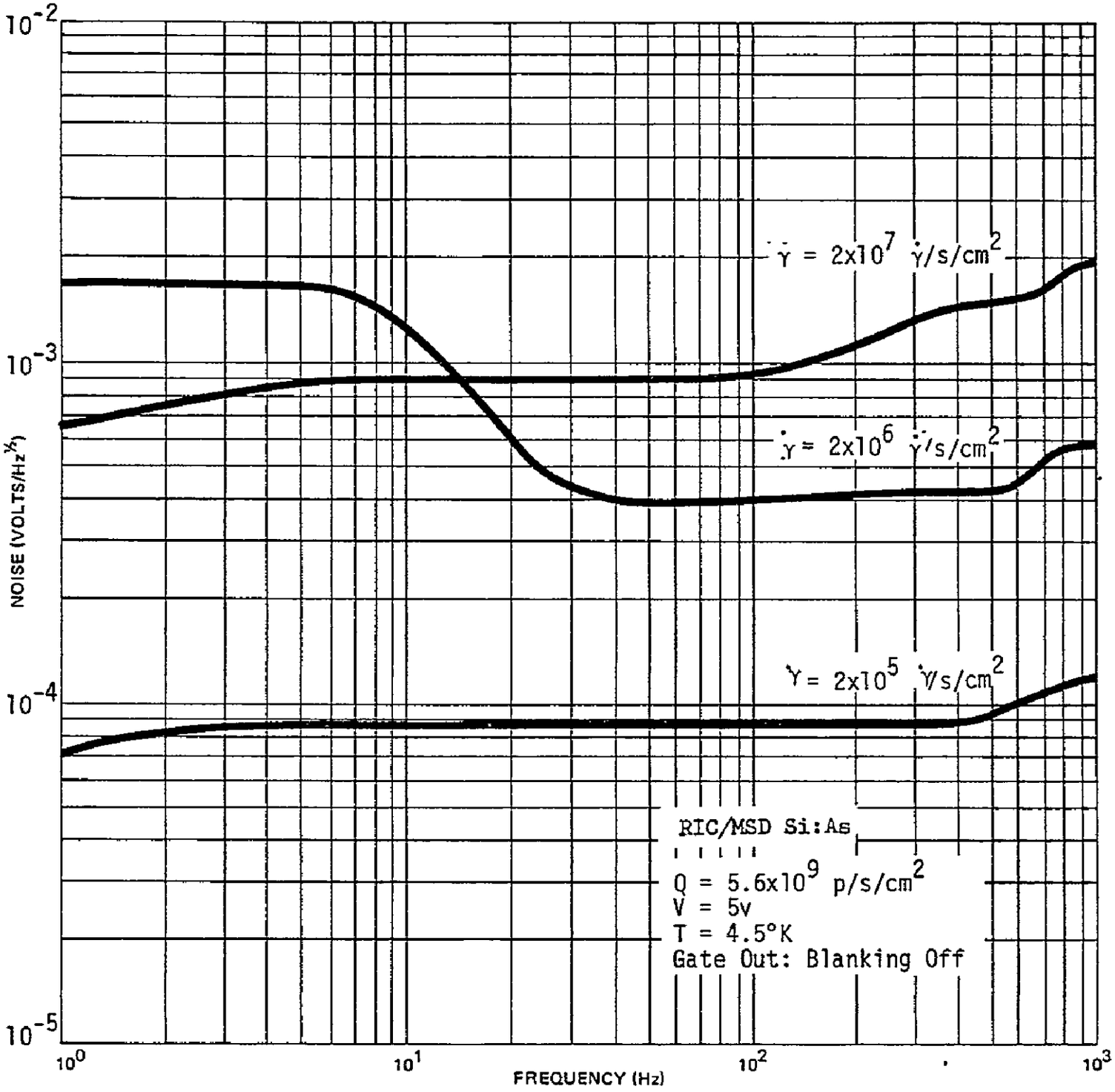

10^{-2}
10^{-3}
10^{-4}
10^{-5}
NOISE (VOLTS/Hz$^{1/2}$)
$\dot{\gamma}$ = 2x10^{7} $\dot{\gamma}$/s/cm^{2}
$\dot{\gamma}$ = 2x10^{6} $\dot{\gamma}$/s/cm^{2}
$\dot{\gamma}$ = 2x10^{5} $\dot{\gamma}$/s/cm^{2}
RIC/MSD Si:As
Q = 5.6x10^{9} p/s/cm^{2}
V = 5v
T = 4.5°K
Gate Out: Blanking Off
10^{0}
10^{1}
10^{2}
10^{3}
FREQUENCY (Hz)

Figure 50

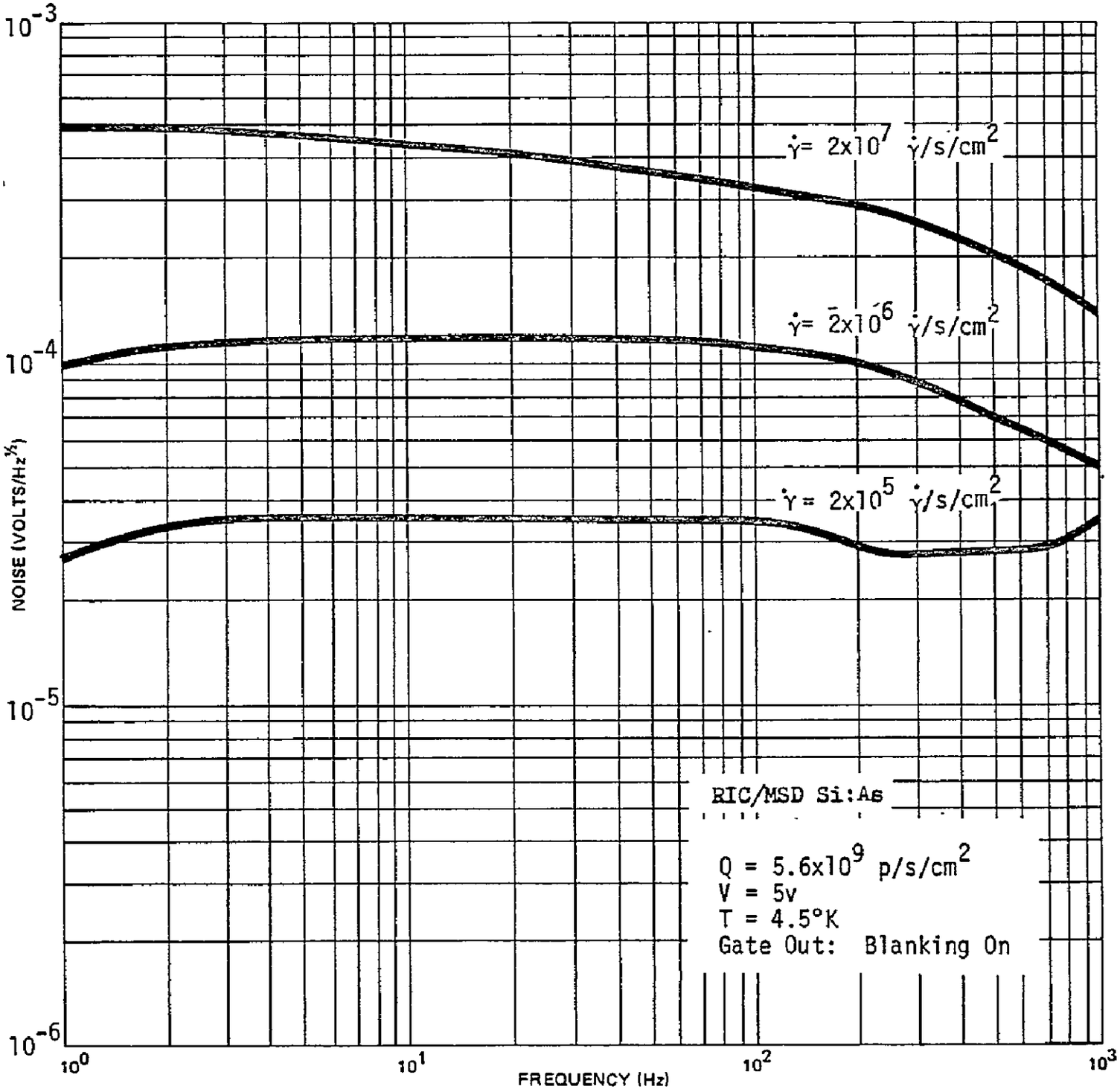

10^{-3}
10^{-4}
10^{-5}
10^{-6}
NOISE (VOLTS/Hz$^{1/2}$)
$\dot{\gamma}$= 2x10^{7} $\dot{\gamma}$/s/cm^{2}
$\dot{\gamma}$= 2x10^{6} $\dot{\gamma}$/s/cm^{2}
$\dot{\gamma}$= 2x10^{5} $\dot{\gamma}$/s/cm^{2}
RIC/MSD Si:As
Q = 5.6x10^{9} p/s/cm^{2}
V = 5v
T = 4.5°K
Gate Out: Blanking On
10^{0}
10^{1}
10^{2}
10^{3}
FREQUENCY (Hz)

Figure 51

5.3 SBRC Si:Sb - Spontaneous Noise Spikes

An attempt was made to characterize the spontaneous noise spikes produced by the new Si:Sb detector (see Section 3.0). However, the output pulses did not have the time dependence usually associated with spontaneous noise spikes. The time shape is illustrated in Figs. 52-59 where detector outputs (using a TIA) are shown as functions of time at two temperatures, four backgrounds, and at biases between 9 and 12 volts.

While there are a few "normal" spikes in the data, most of the spikes at higher bias have a relatively slow rise time and, in some cases, appear to be almost symmetrical. Because of the slow rise times, it was not possible to use triggered-circuitry to obtain pulse rates or amplitude distribution data. However, it is apparent from the data that the conclusions made in Section 5.1.1 also hold for this detector. That is, the pulse rate increases with increasing bias, operating temperature, and photon background flux.

As was mentioned in Section 3.0, the optimum bias determined at 4.5K was 9 volts. If one looks at the 4.5K data presented here at biases greater than 9 volts, it is apparent that spikes will contribute to the rms noise. However, at 2.5K, the increase in rms noise due to spikes (at biases greater than 9 volts) appears to be somewhat smaller. This leads to the conclusion that biases greater than 9 volts may be optimum at the lower temperature.

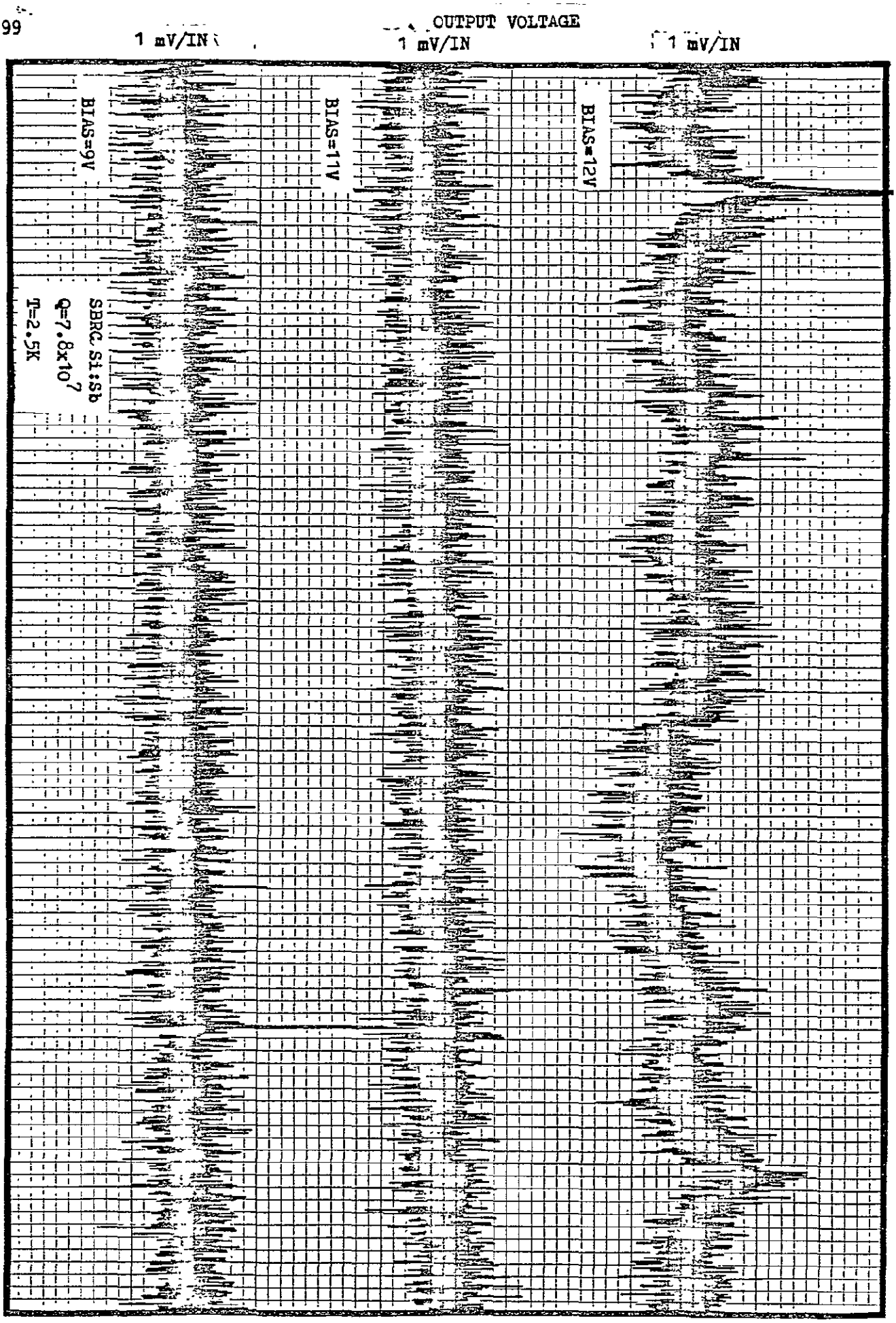

OUTPUT VOLTAGE
1 mV/IN
1 mV/IN
1 mV/IN
BIAS=12V
BIAS=11V
BIAS=9V
SBRC Si:Sb
Q=7.8x10^7
T=2.5K
TIME : 10 SEC/IN

Figure 52

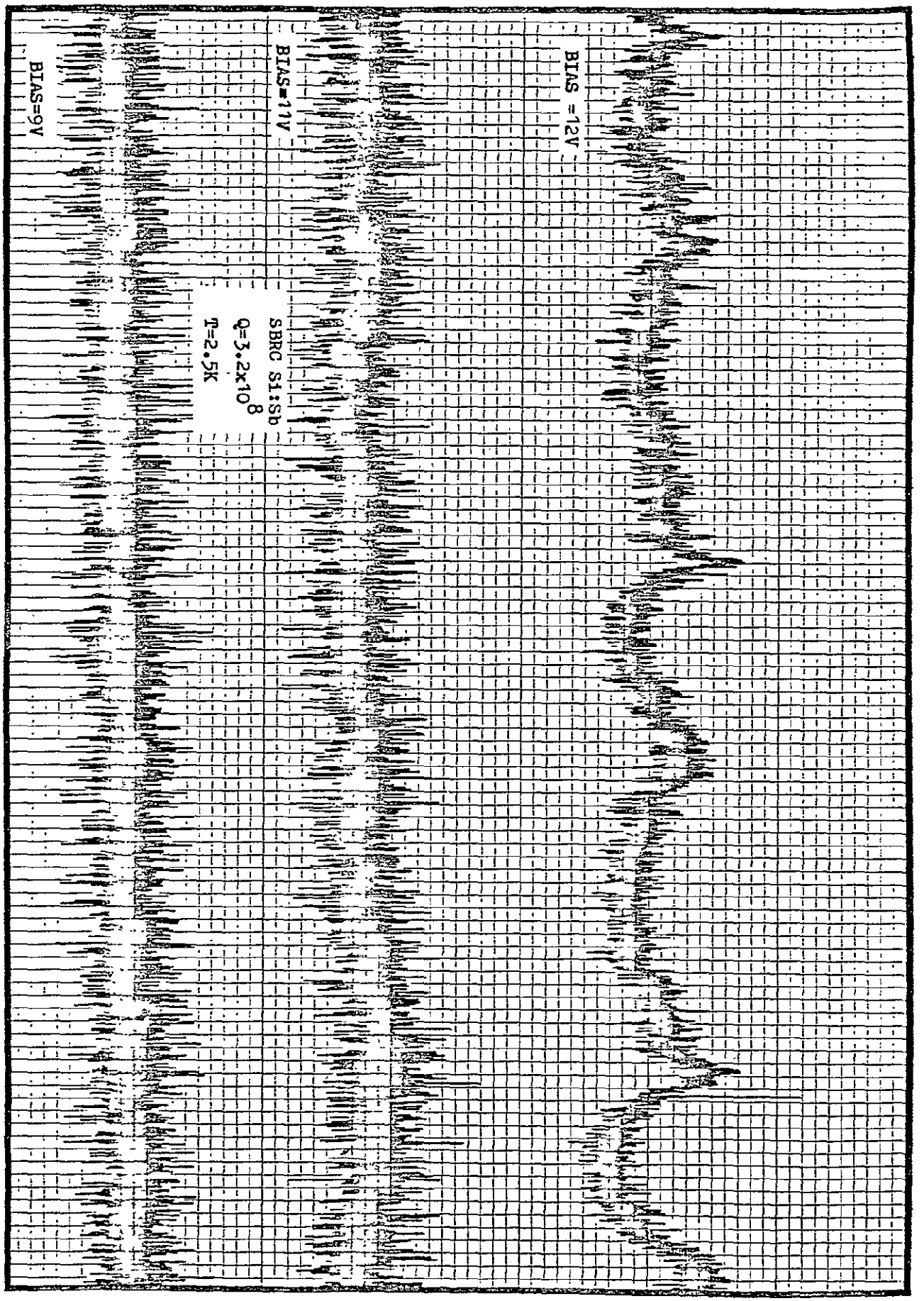

OUTPUT VOLTAGE
1 mV/IN
1 mV/IN
2 mV/IN
BIAS=9V
BIAS=11V
BIAS =12V
SBRC S1:Sb
Q=3.2x10^8
T=2.5K
TIME 10 SEC/IN

Figure 53

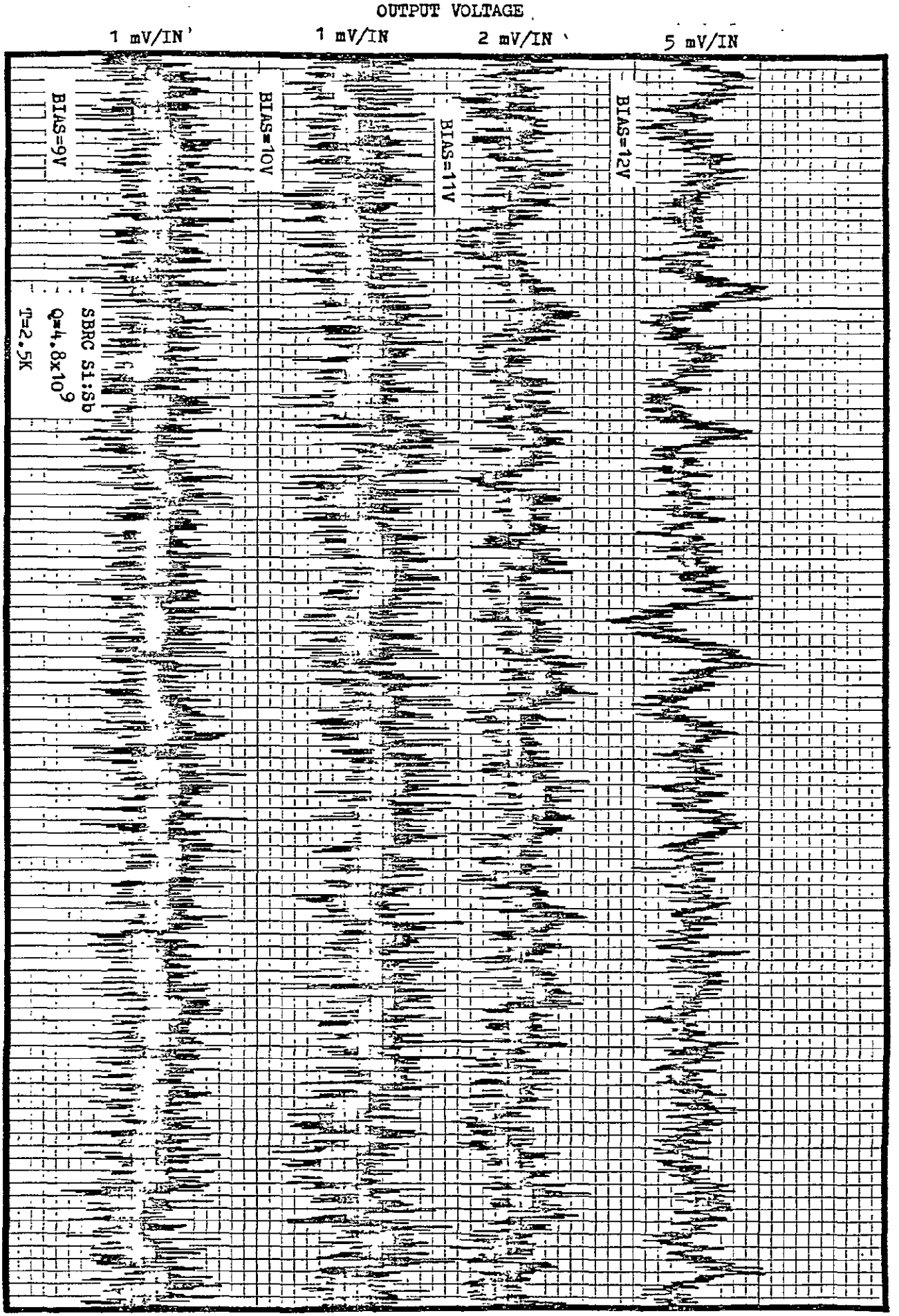

OUTPUT VOLTAGE
1 mV/IN
1 mV/IN
2 mV/IN
5 mV/IN
BIAS=9V
BIAS=10V
BIAS=11V
BIAS=12V
SBRC Si:Sb
Q=4.8x10^9
T=2.5K
TIME 2 SEC/IN

Figure 54

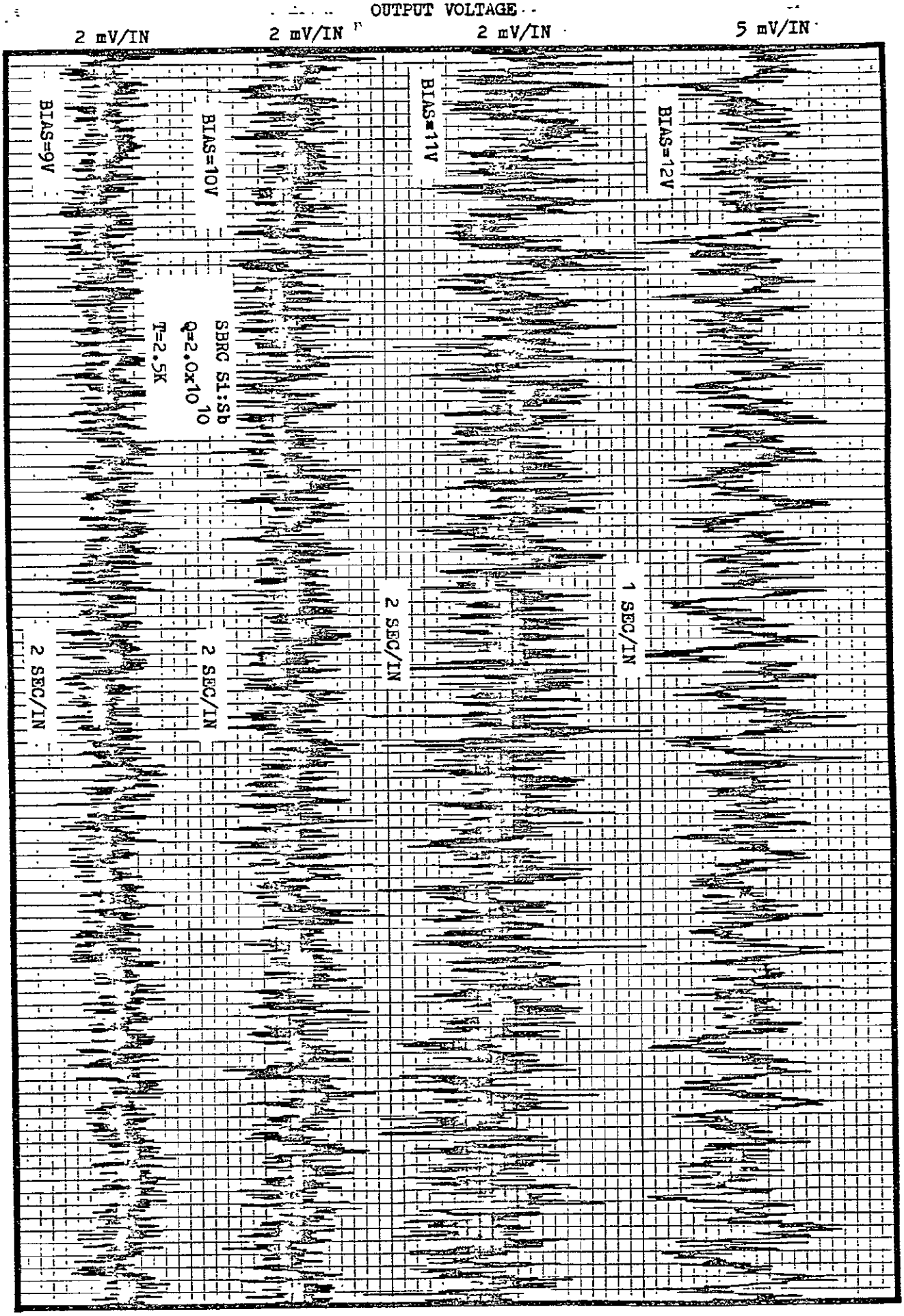

OUTPUT VOLTAGE
2 mV/IN
2 mV/IN
2 mV/IN
5 mV/IN
BIAS=9V
BIAS=10V
BIAS=11V
BIAS=12V
SBRC Si:Sb
Q=2.0x10^10
T=2.5K
2 SEC/IN
2 SEC/IN
2 SEC/IN
1 SEC/IN
TIME

Figure 55

OUTPUT VOLTAGE
10 mV/IN
1 mV/IN
1 mV/IN
BIAS=12V
5 SEC/IN
BIAS=11V
10 SEC/IN
BIAS=10V
20 SEC/IN
SBRC Si:Sb
Q=7.8x10^7
T=4.5K
TIME

Figure 56

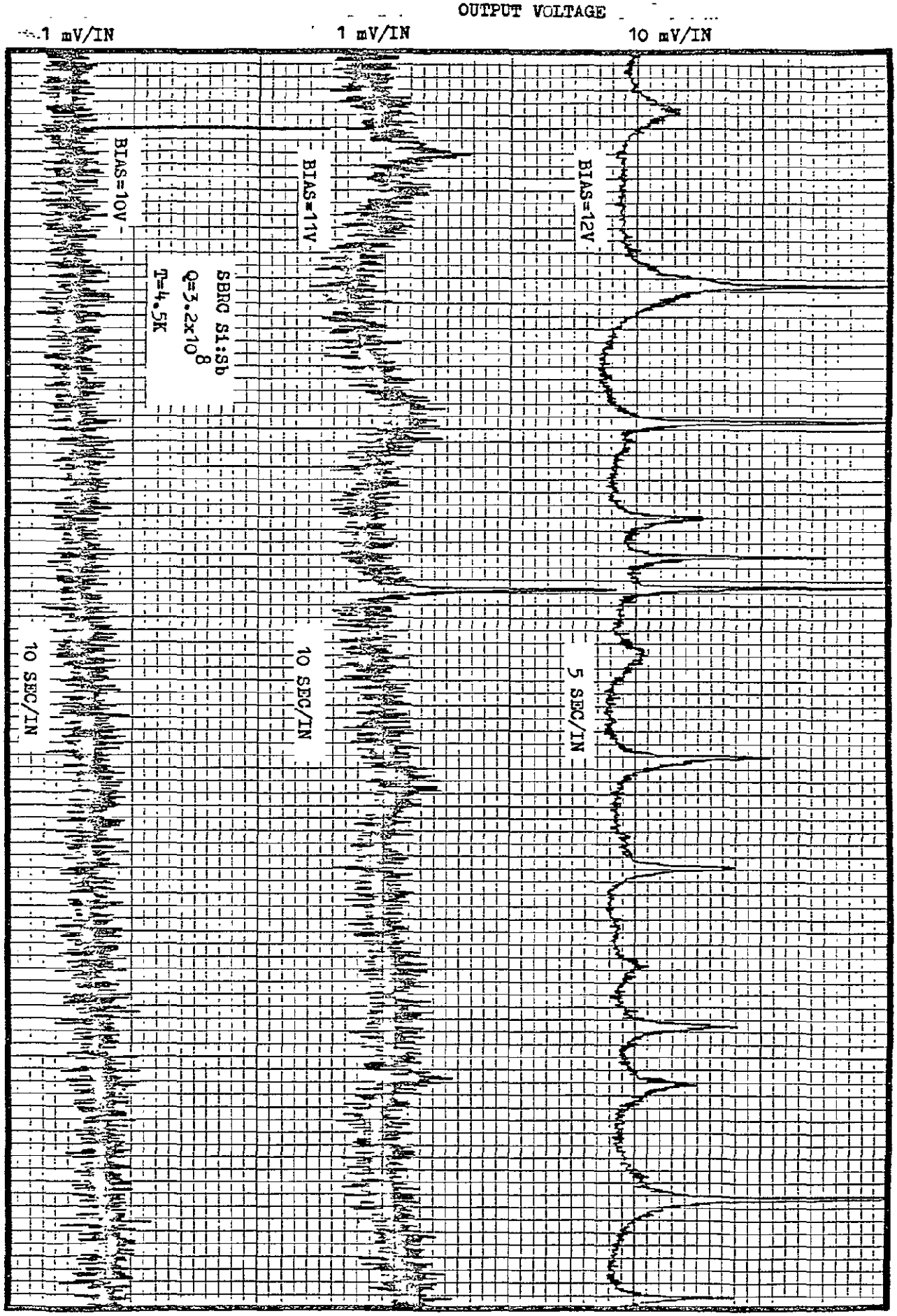

OUTPUT VOLTAGE
.1 mV/IN
1 mV/IN
10 mV/IN
BIAS=10V
BIAS=11V
BIAS=12V
SBRC Si:Sb
Q=3.2x10^8
T=4.5K
10 SEC/IN
10 SEC/IN
5 SEC/IN
TIME

Figure 57

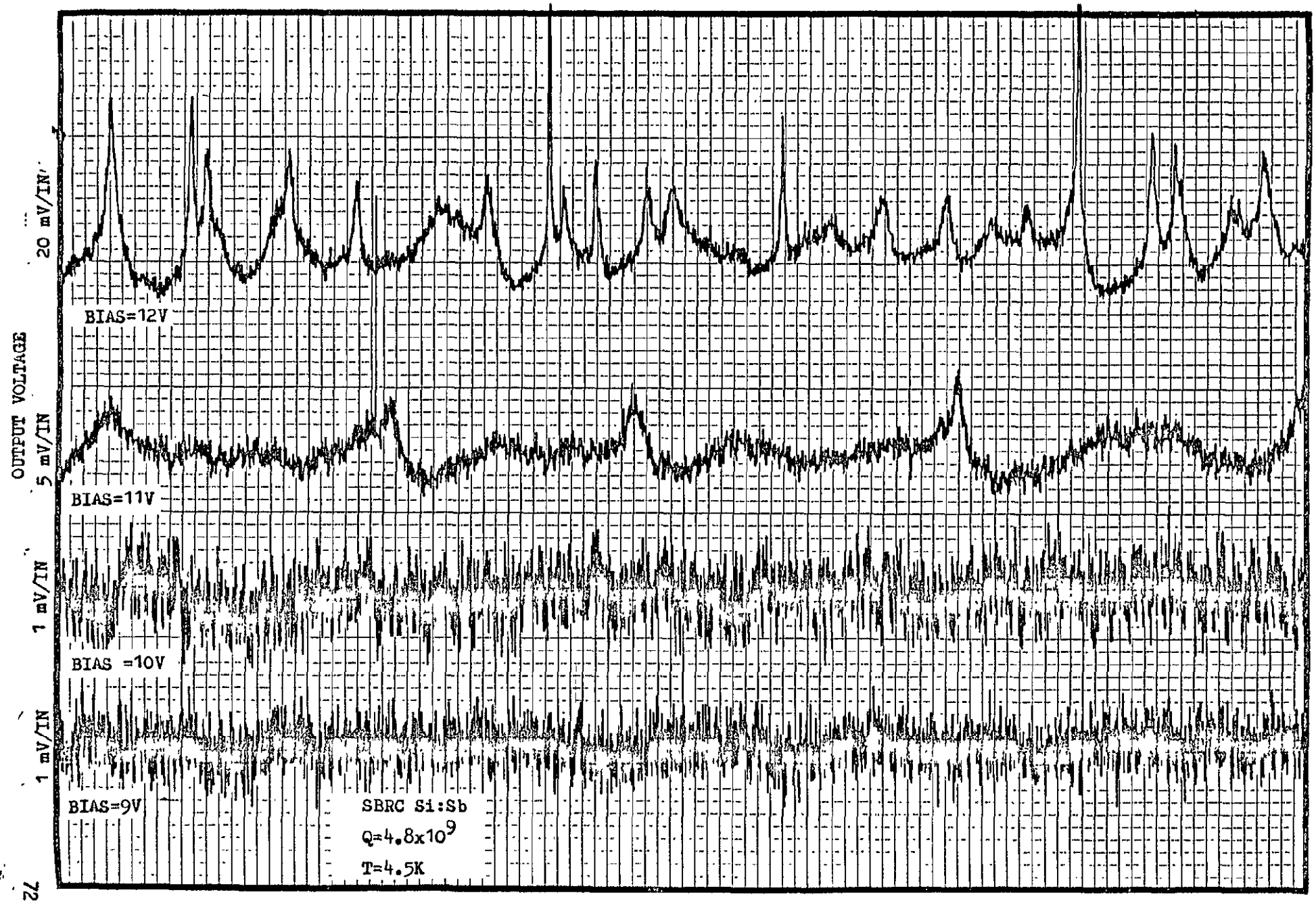

OUTPUT VOLTAGE
20 mV/IN
5 mV/IN
1 mV/IN
1 mV/IN
BIAS=12V
BIAS=11V
BIAS =10V
BIAS=9V
SBRC Si:Sb
Q=4.8x10^9
T=4.5K
TIME 1 SEC/IN

Figure 58

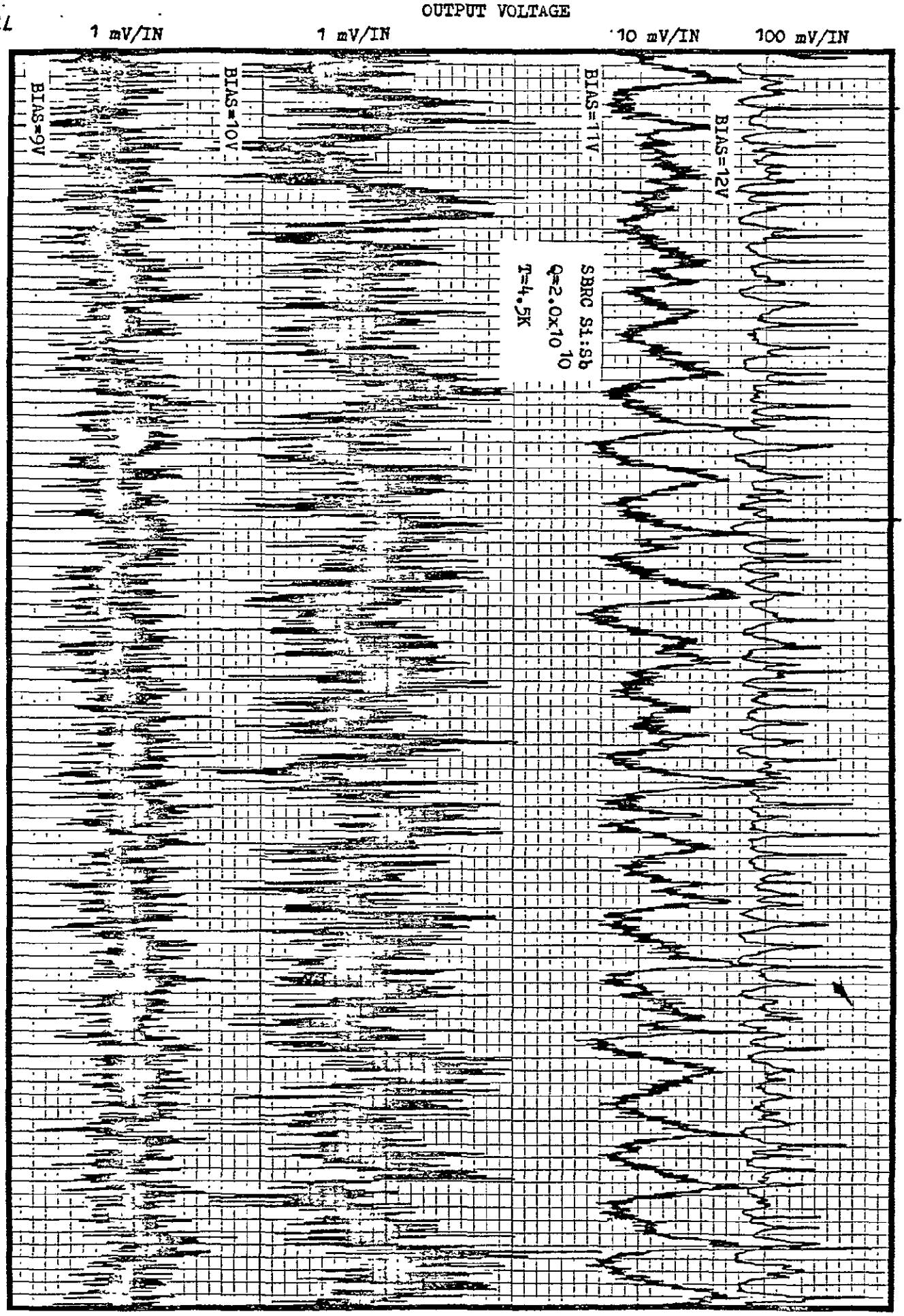

OUTPUT VOLTAGE
1 mV/IN
1 mV/IN
10 mV/IN
100 mV/IN
BIAS=9V
BIAS=10V
BIAS=11V
BIAS=12V
SBRC Si:Sb
Q=2.0x10^10
T=4.5K
TIME : 1 SEC/IN

Figure 59

6.0 DC-COUPLED OUTPUT MEASUREMENTS

A number of measurements were made to characterize the response of two detectors to step function changes in background photon flux. The detectors used were the SBRC Si:As (previously reported) and the new SBRC Si:Sb (Section 3.0). For these measurements a TIA was used and the electronics were dc-coupled from the detector to the recording device. The data for the Si:As detector are given in Figs. 60-106. Figures 107-130 show the data for the Si:Sb detector.

The background levels shown on the graphs are equivalent photon flux densities at the peak wavelength of each detector. That is, the relative spectral response of each detector and the spectral distribution of the photons from the source were taken into account in each case. Data are presented at two operating temperatures and four gackgrounds for each detector. Two bias values (6 volts and 12 volts) were used for the Si:As detector. Because batteries were used in a number of places in the circuit, a long term dc-drift appears in some of the data. This drift is particularly noticeable where the output sensitivity is high. For instance, in Fig. 82 there is a drift of about 600μV in 500 sec.

It is very difficult to make any general conclusions from these data. The output wave shape appears to be a function of every possible variable (i.e., initial background, final background, bias, temperature, etc.). Figures 101-106 show the output of the Si:As detector at biases ranging from +4 V to +12 V and from -4 V to -12 V. It is apparent from these data that the shape of the signal pulse also depends on the polarity of the bias. It should be pointed out that the data in this Section was quite reproducible. For example, the rather complicated output shown in Fig. 87 could be duplicated (the smplitude of the pulses varied somewhat) time after time.

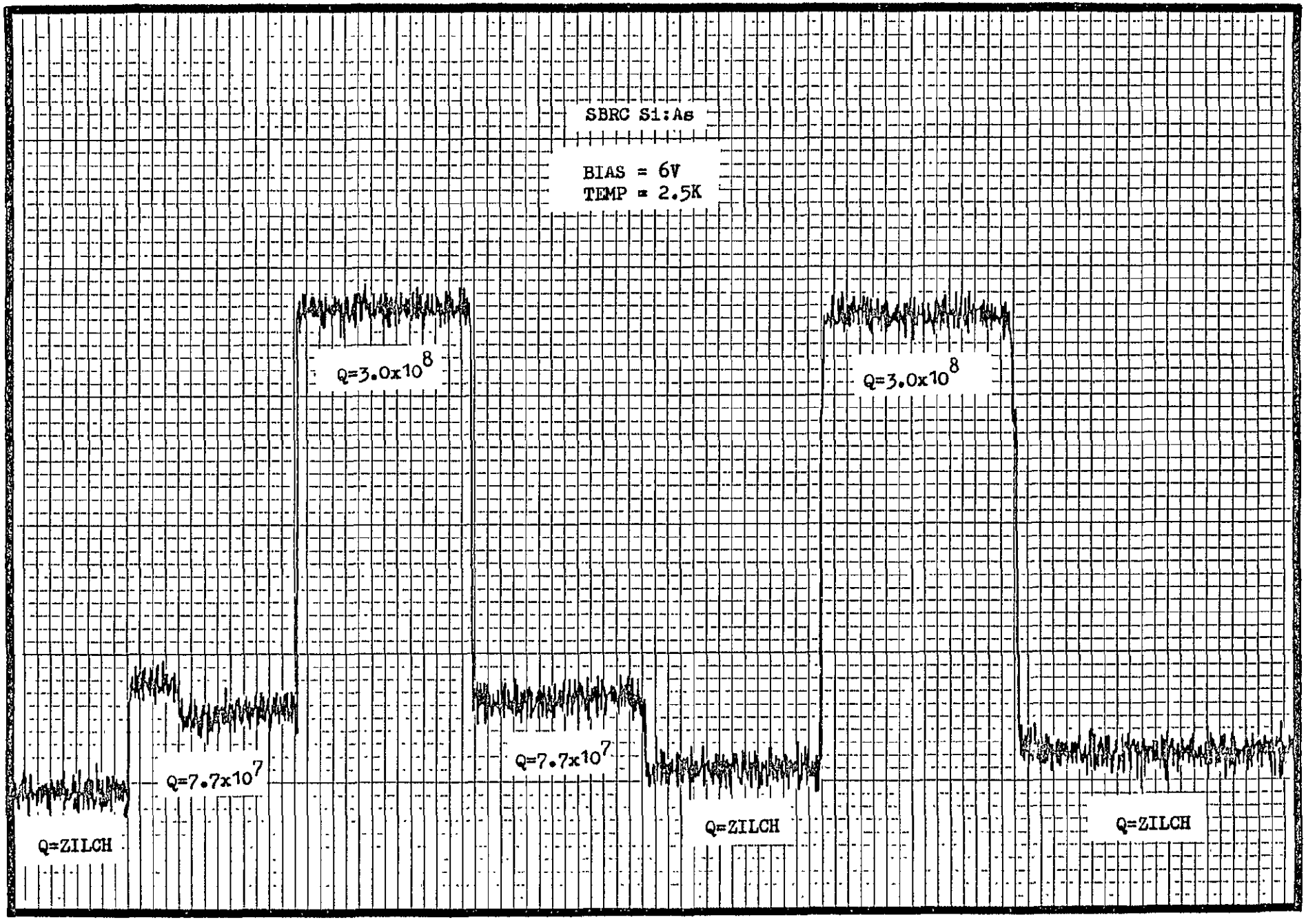

SBRC S1:As
BIAS = 6V
TEMP = 2.5K
Q=3.0x10^8
Q=3.0x10^8
Q=7.7x10^7
Q=7.7x10^7
Q=ZILCH
Q=ZILCH
Q=ZILCH
OUTPUT (1 mV/IN)
TIME (10 SEC/IN)

Figure 60

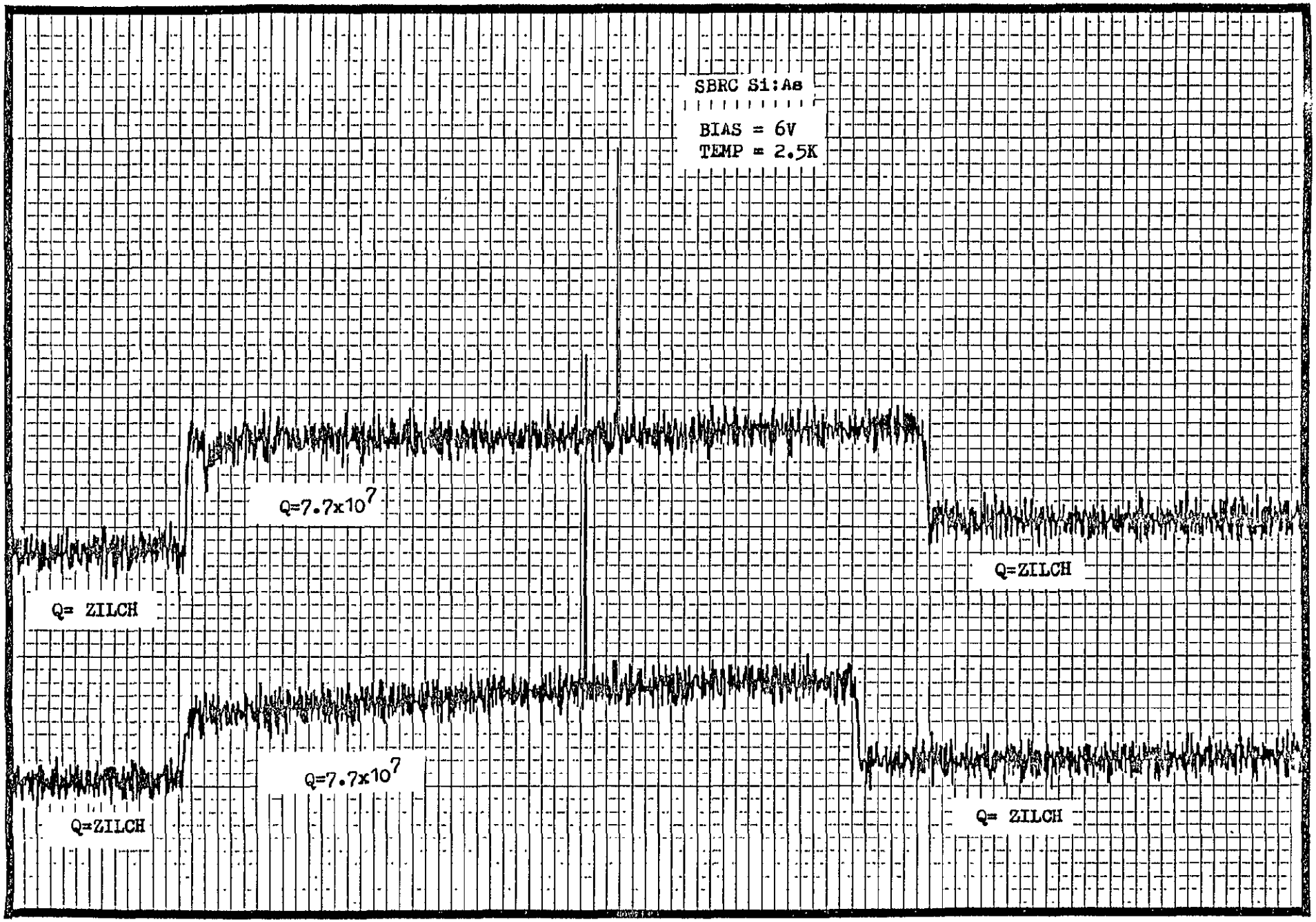

SBRC Si:As
BIAS = 6V
TEMP = 2.5K
Q=7.7x10^7
Q= ZILCH
Q=ZILCH
Q=7.7x10^7
Q=ZILCH
Q= ZILCH
OUTPUT (1 mV/IN)
TIME (10 SEC/IN)

Figure 61

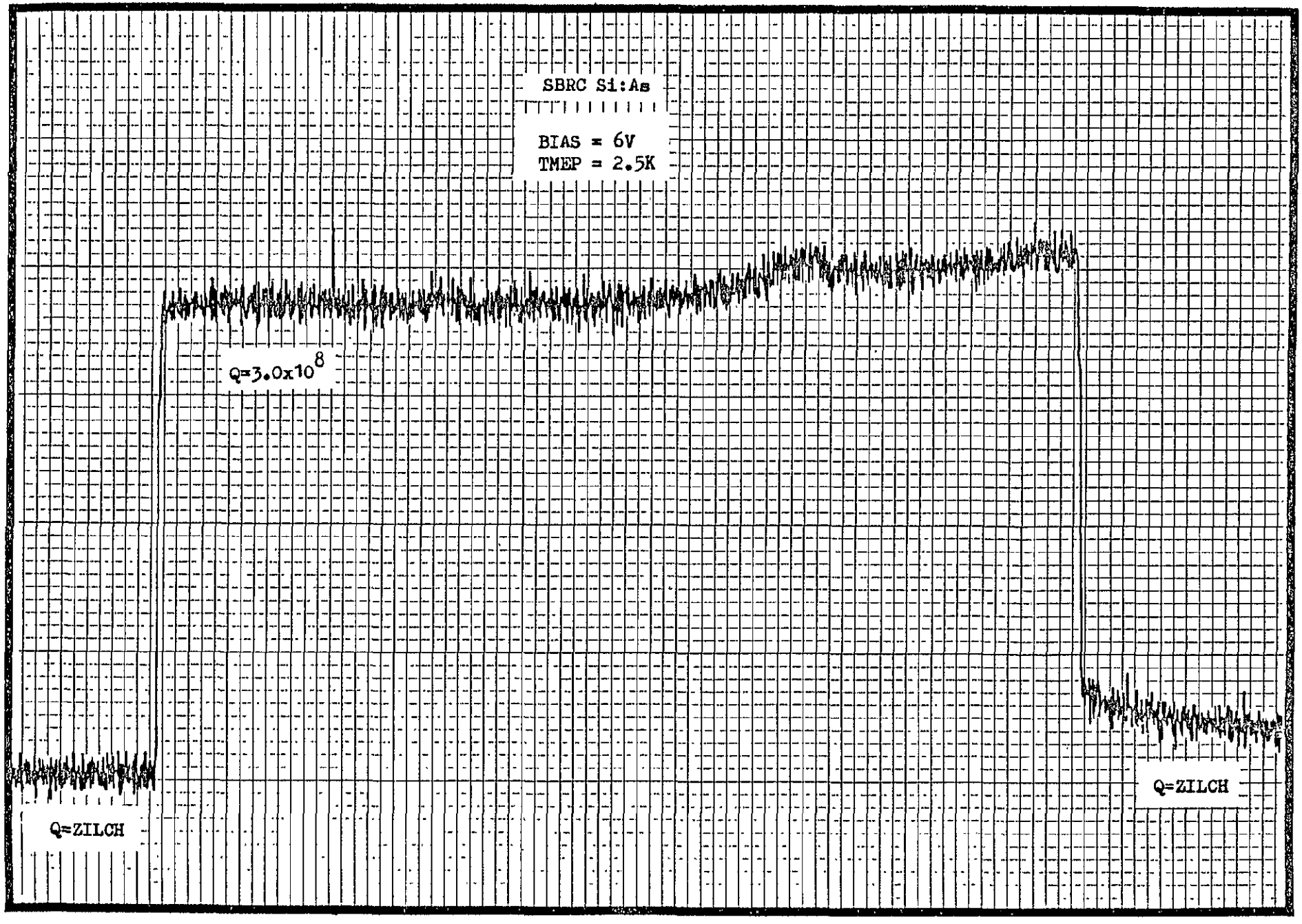

SBRC Si:As
BIAS = 6V
TMEP = 2.5K
Q=3.0x10^8
Q=ZILCH
Q=ZILCH
OUTPUT (1 mV/IN)
TIME (10 SEC/IN)

Figure 62

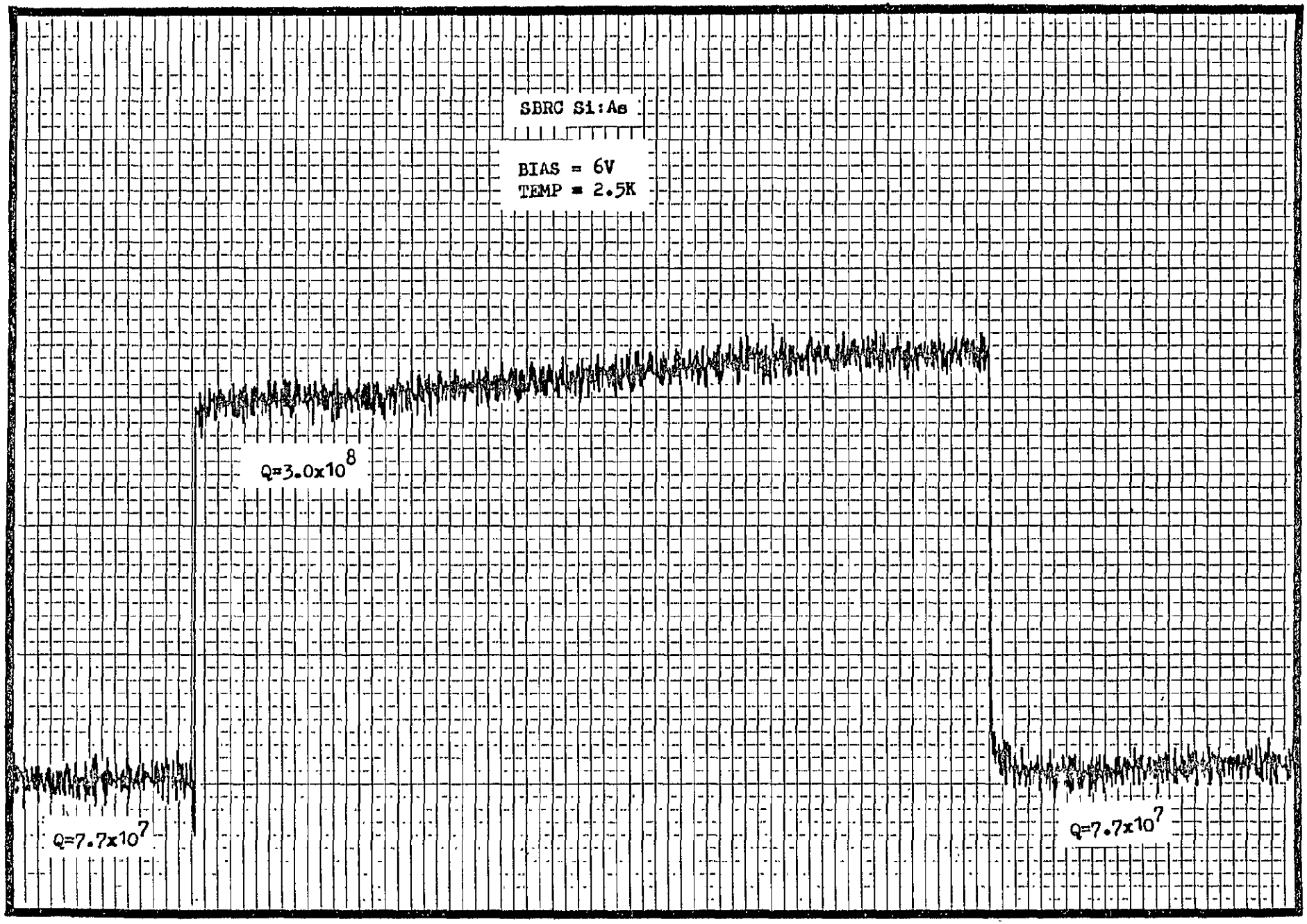

SBRC Si:As
BIAS = 6V
TEMP = 2.5K
Q=3.0x10^8
Q=7.7x10^7
Q=7.7x10^7
OUTPUT (1 mV/IN)
TIME (10 SEC/IN)

Figure 63

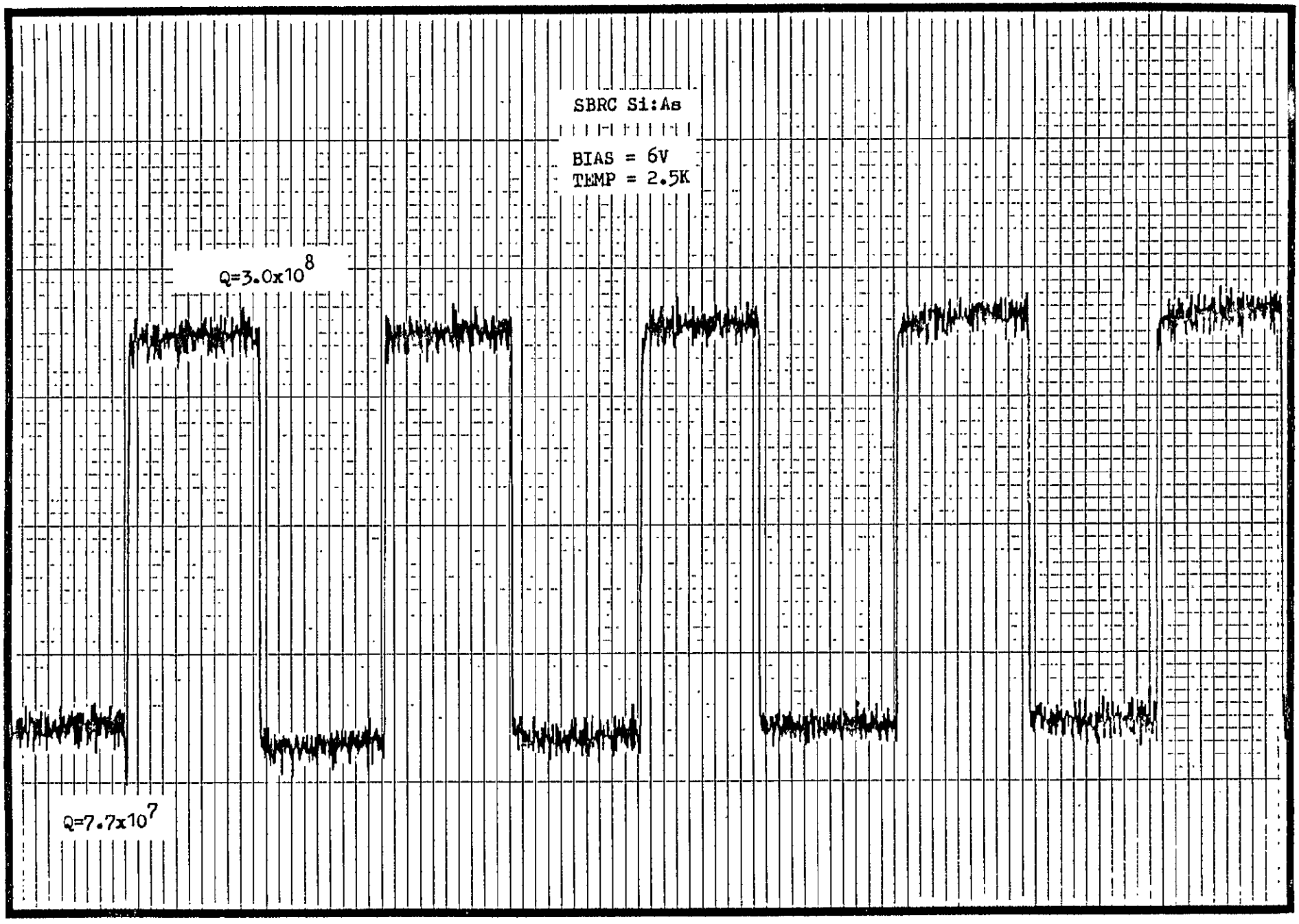

SBRC Si:As
BIAS = 6V
TEMP = 2.5K
Q=3.0x10^8
Q=7.7x10^7
OUTPUT (1 mV/IN)
TIME (10 SEC/IN)

Figure 64

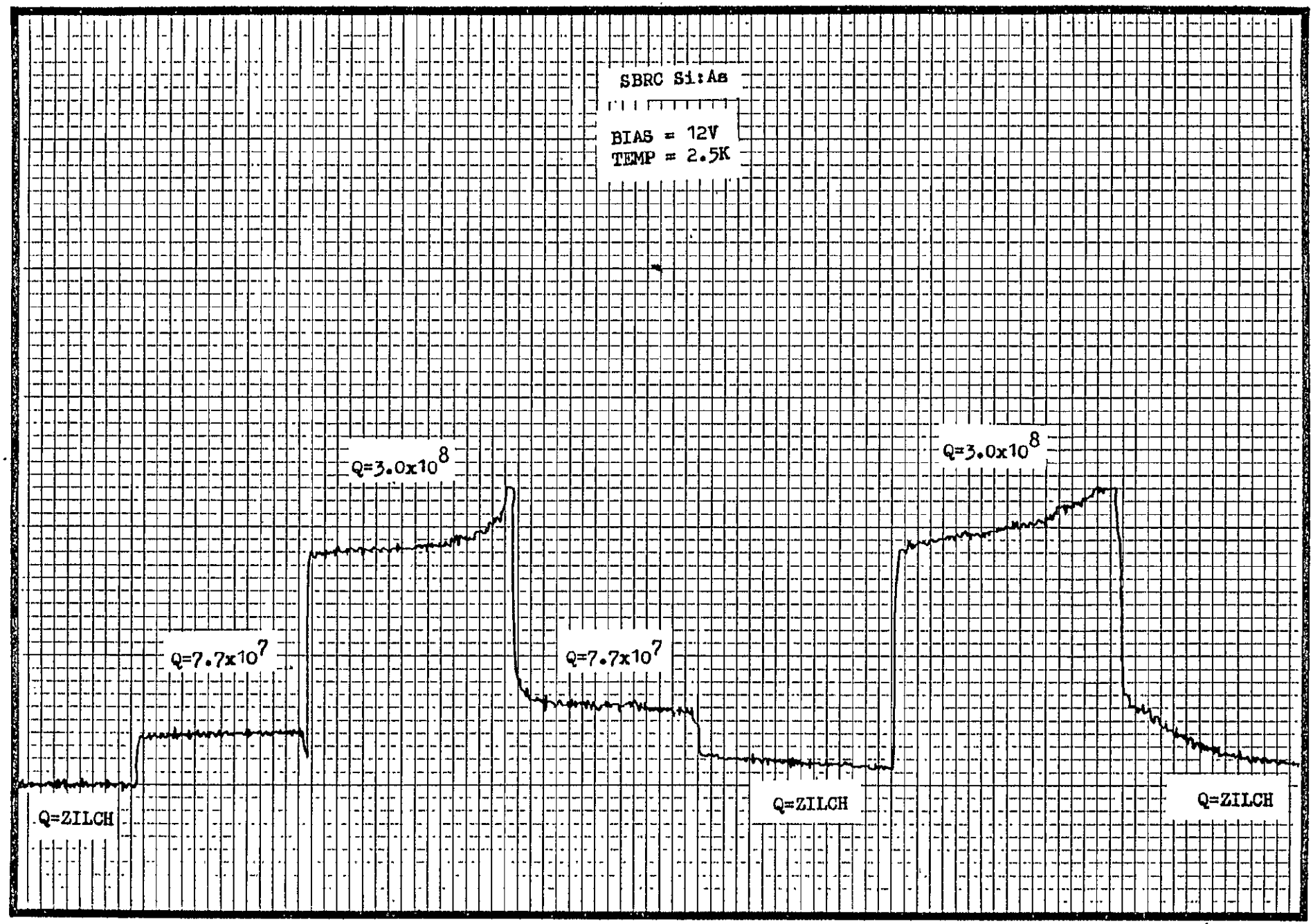

SBRC Si:As
BIAS = 12V
TEMP = 2.5K
Q=3.0x10^8
Q=7.7x10^7
Q=7.7x10^7
Q=3.0x10^8
Q=ZILCH
Q=ZILCH
Q=ZILCH
OUTPUT (5mV/IN)
TIME (10 SEC/IN)

Figure 65.

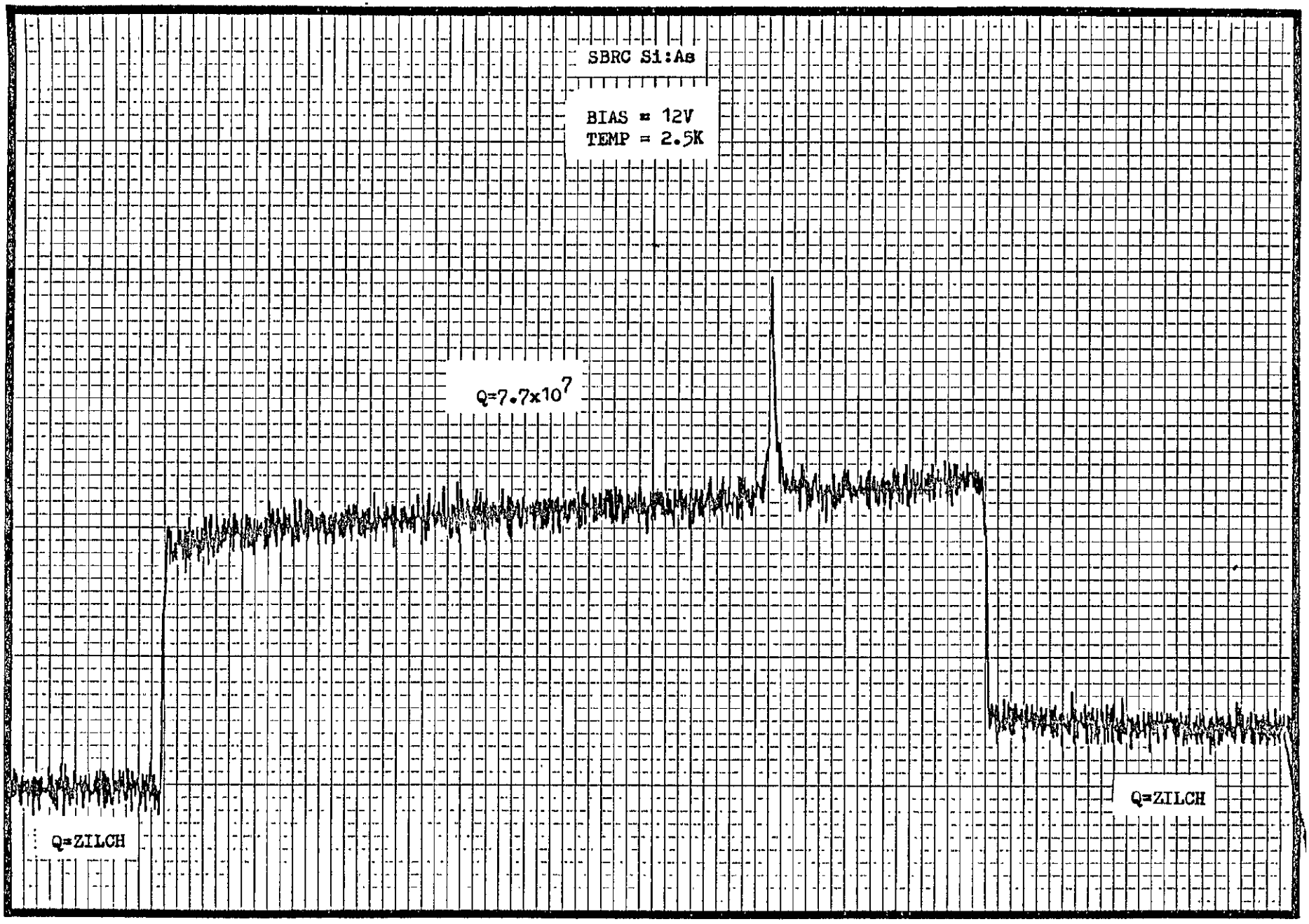

SBRC Si:As
BIAS = 12V
TEMP = 2.5K
Q=7.7x10^7
Q=ZILCH
Q=ZILCH
OUTPUT (1 mV/IN)
TIME (10 SEC/IN)

Figure 66

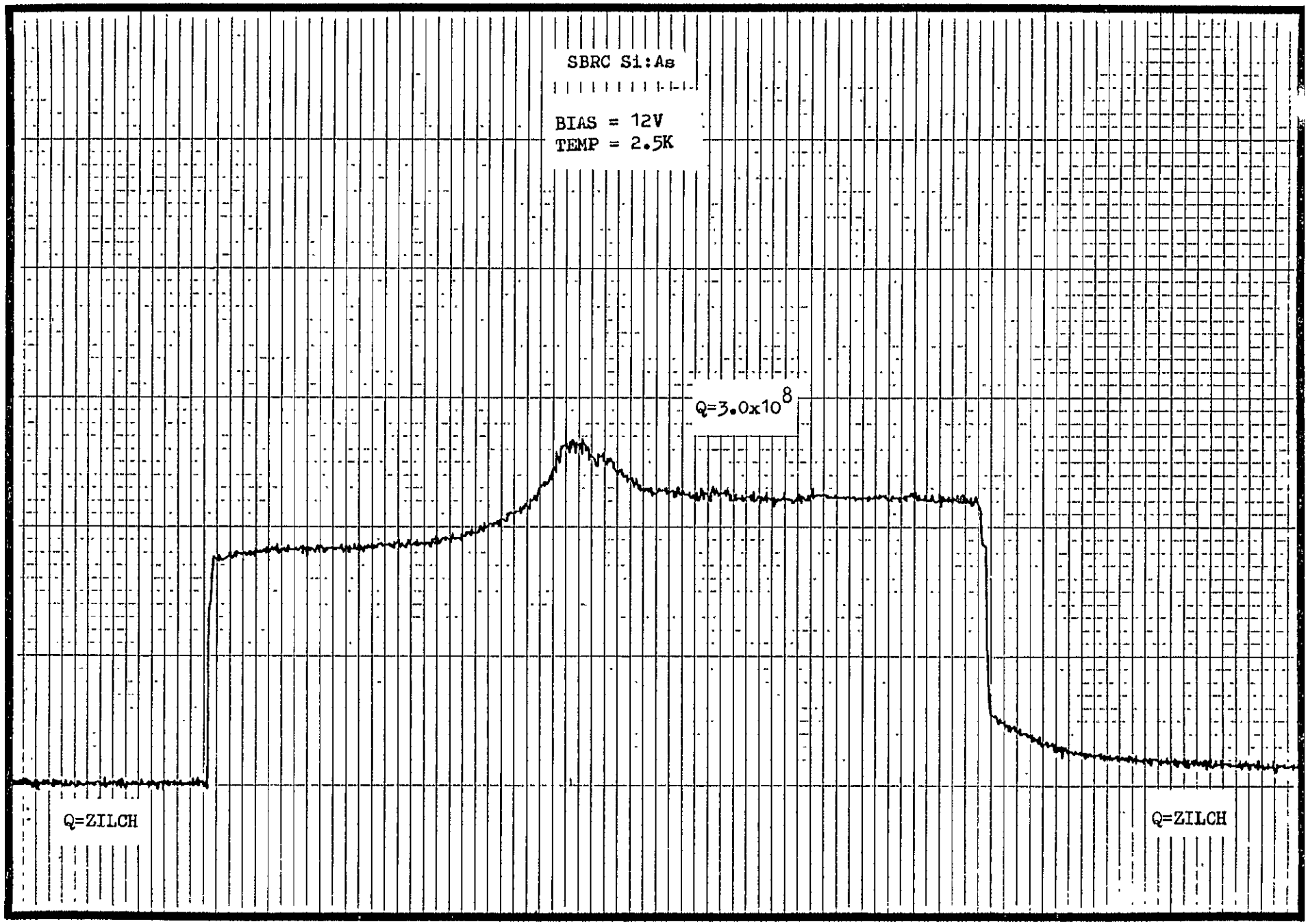

SBRC Si:As
BIAS = 12V
TEMP = 2.5K
Q=3.0x10^8
Q=ZILCH
Q=ZILCH
OUTPUT (5 mV/IN)
TIME (10 SEC/IN)

Figure 67

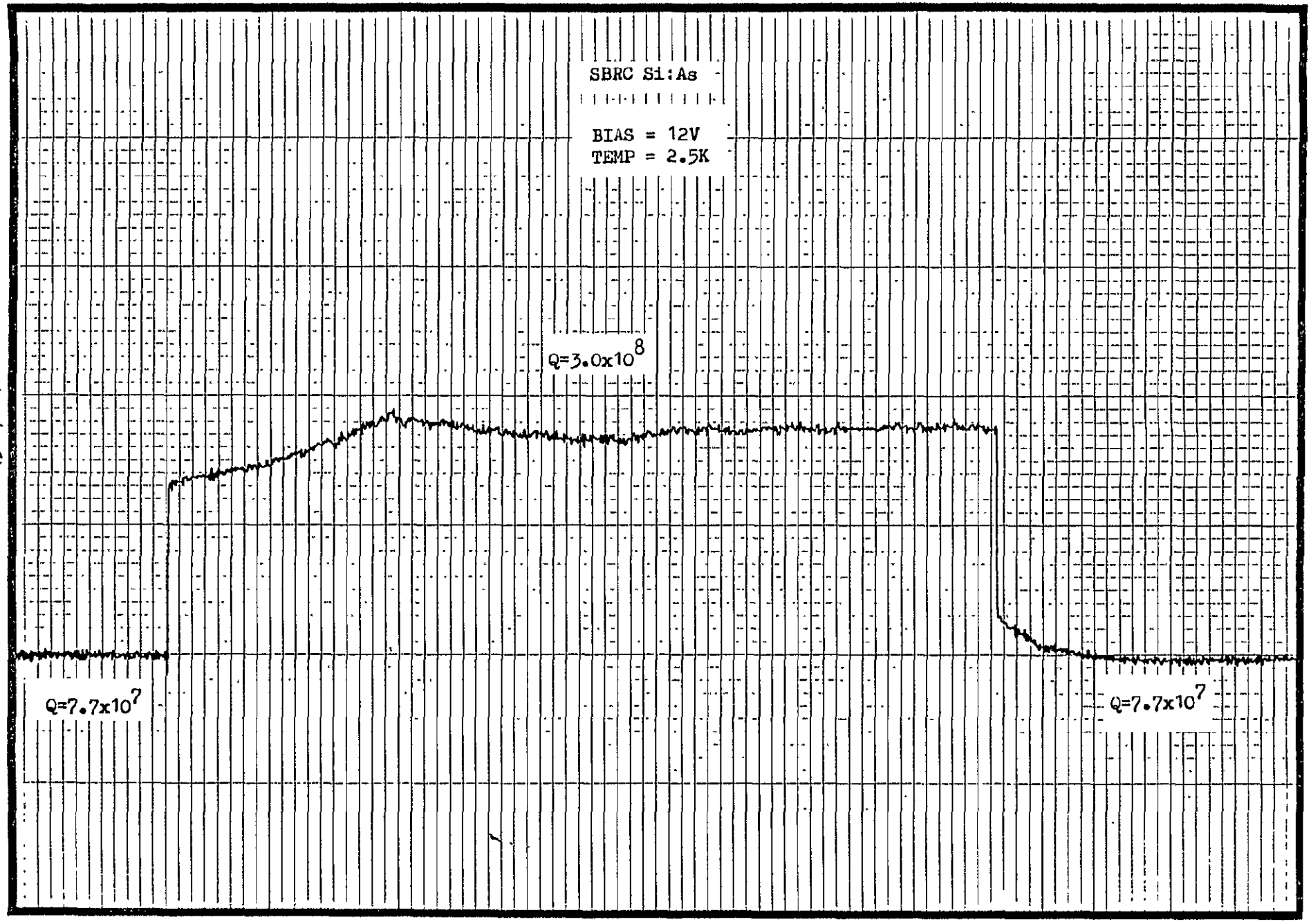

SBRC Si:As
BIAS = 12V
TEMP = 2.5K
Q=3.0x10^8
Q=7.7x10^7
Q=7.7x10^7
OUTPUT (5mV/IN)
TIME (10 SEC/IN)

Figure 68

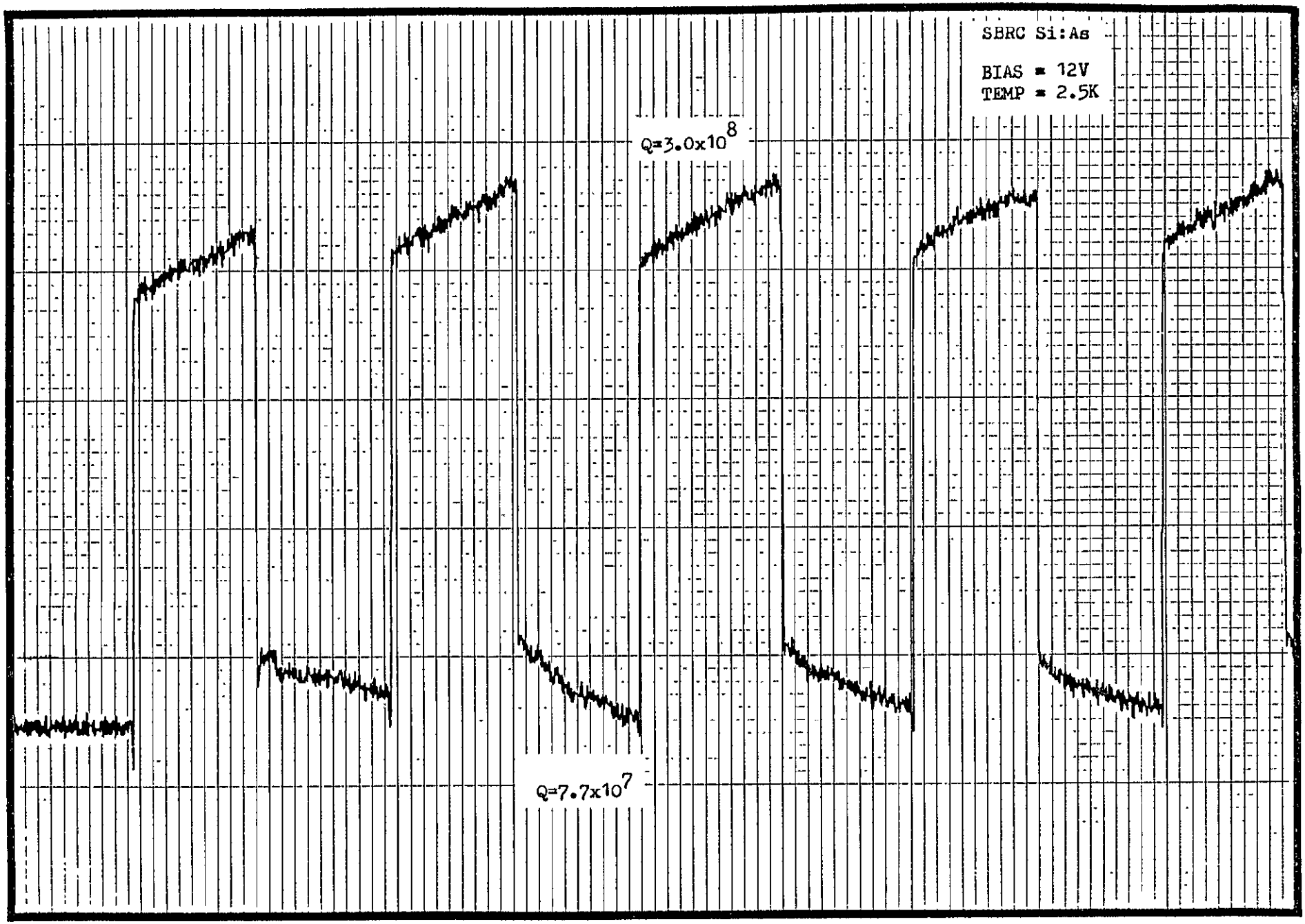

SBRC Si:As
BIAS = 12V
TEMP = 2.5K
Q=3.0x10^8
Q=7.7x10^7
OUTPUT (2 mV/IN)
TIME (10 SEC/IN)

Figure 69

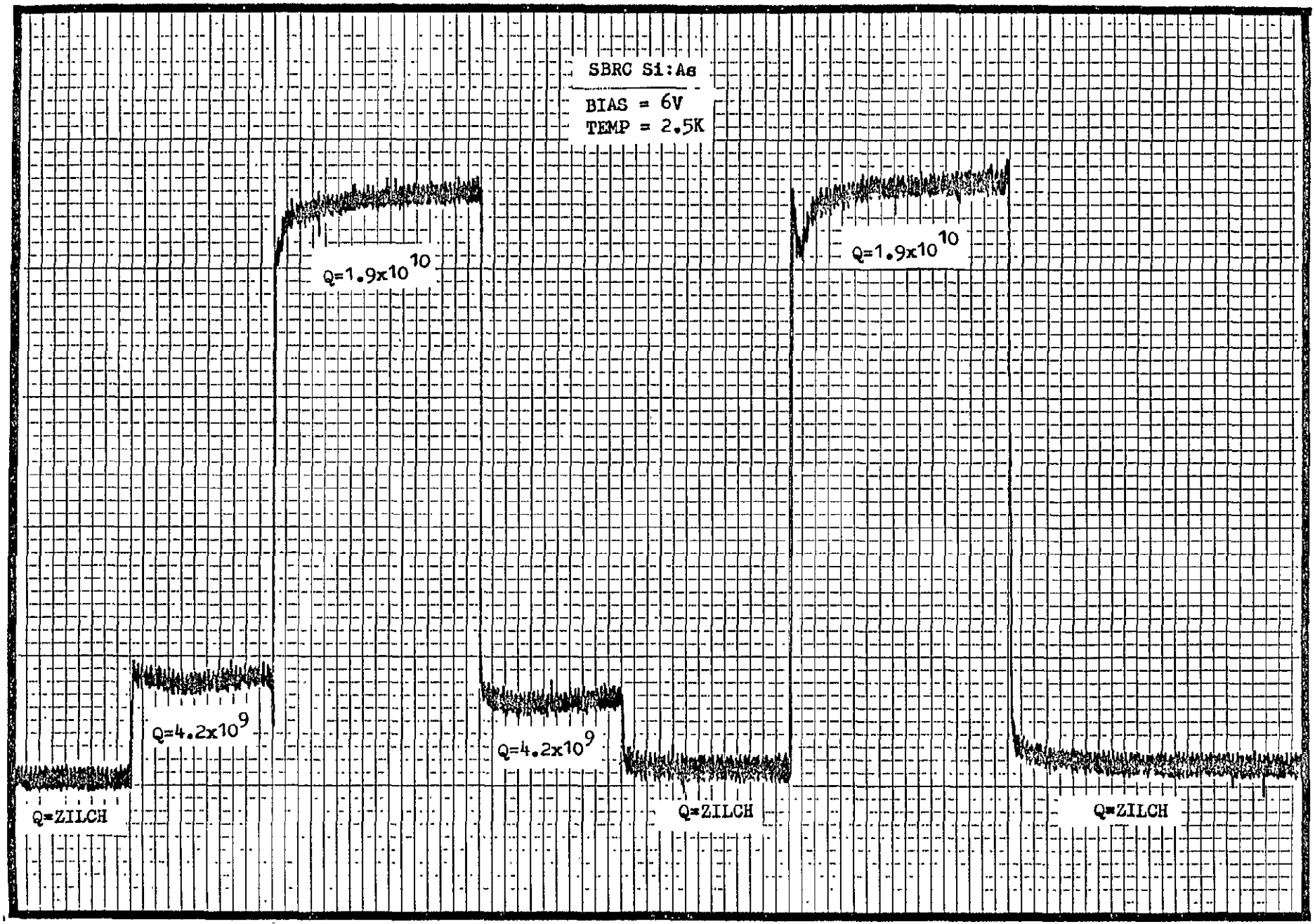

SBRC Si:As
BIAS = 6V
TEMP = 2.5K
Q=1.9x10^10
Q=1.9x10^10
Q=4.2x10^9
Q=4.2x10^9
Q=ZILCH
Q=ZILCH
Q=ZILCH
OUTPUT (50 mV/IN)
TIME (10 SEC/IN)

Figure 70

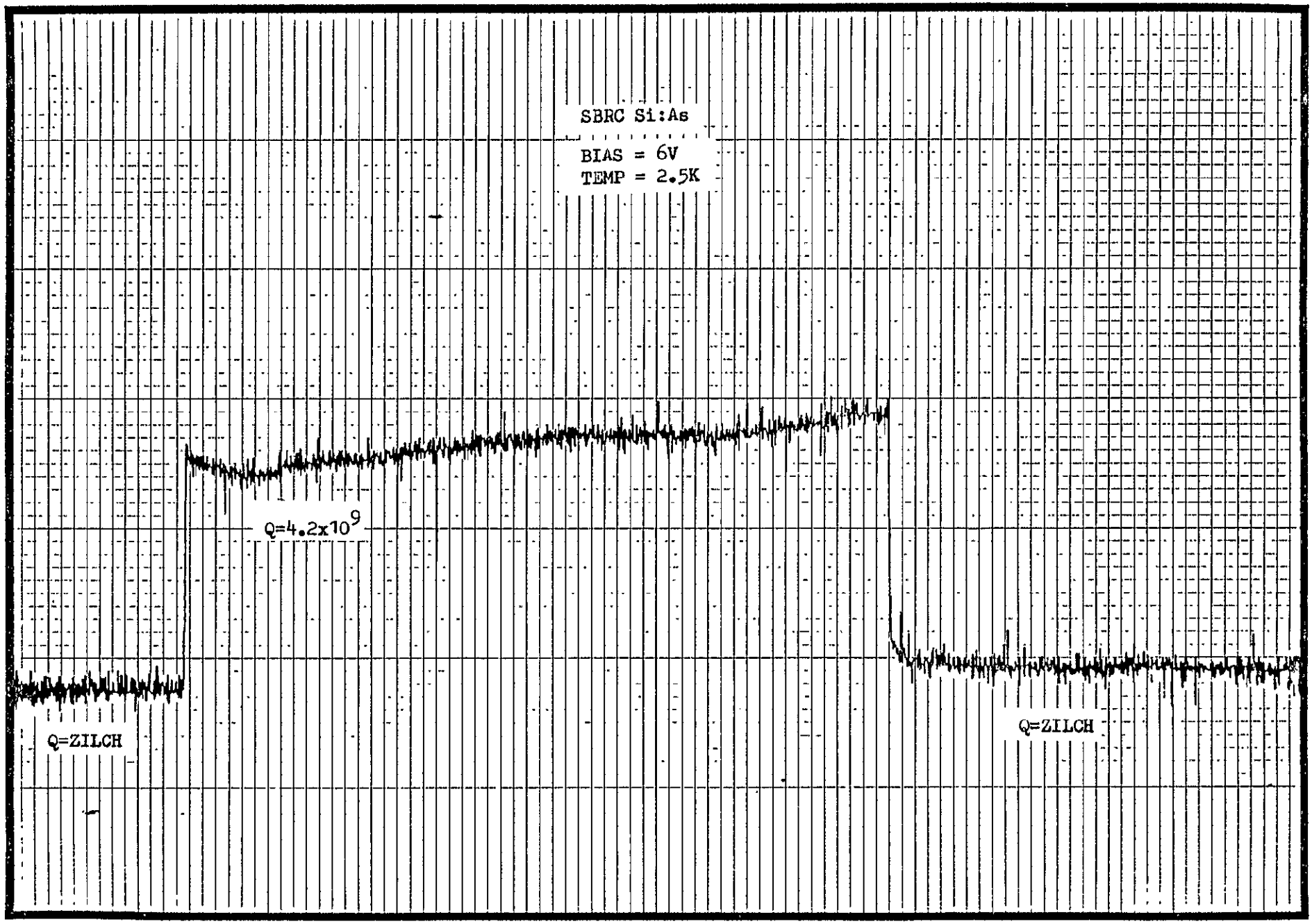

SBRC Si:As
BIAS = 6V
TEMP = 2.5K
Q=4.2x10^9
Q=ZILCH
Q=ZILCH
OUTPUT (20 mV/IN)
TIME (10 SEC/IN)

Figure 71

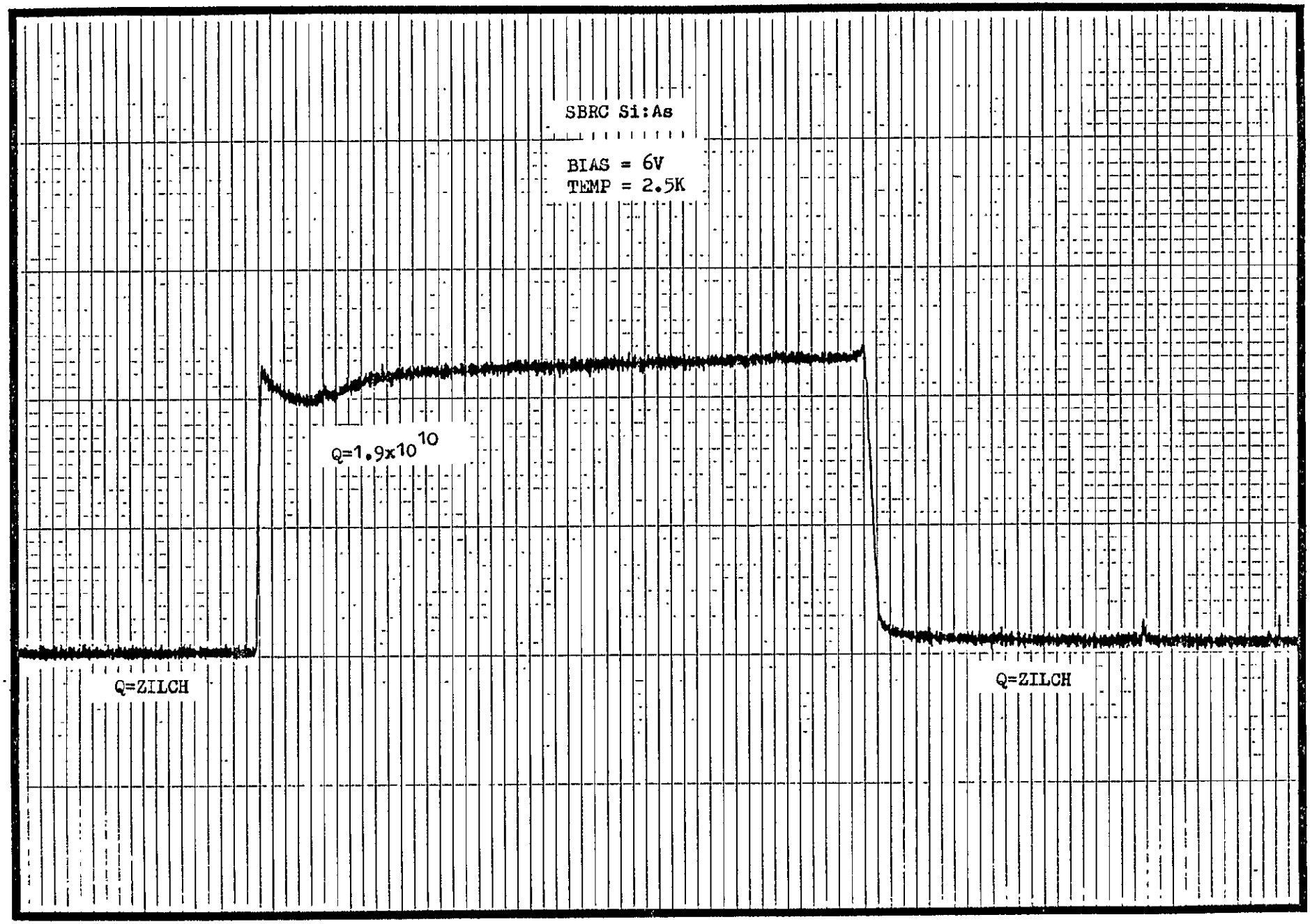

SBRC Si:As
BIAS = 6V
TEMP = 2.5K
Q=1.9x10^10
Q=ZILCH
Q=ZILCH
OUTPUT (100 mV/IN)
TIME (2 SEC/IN)

Figure 72

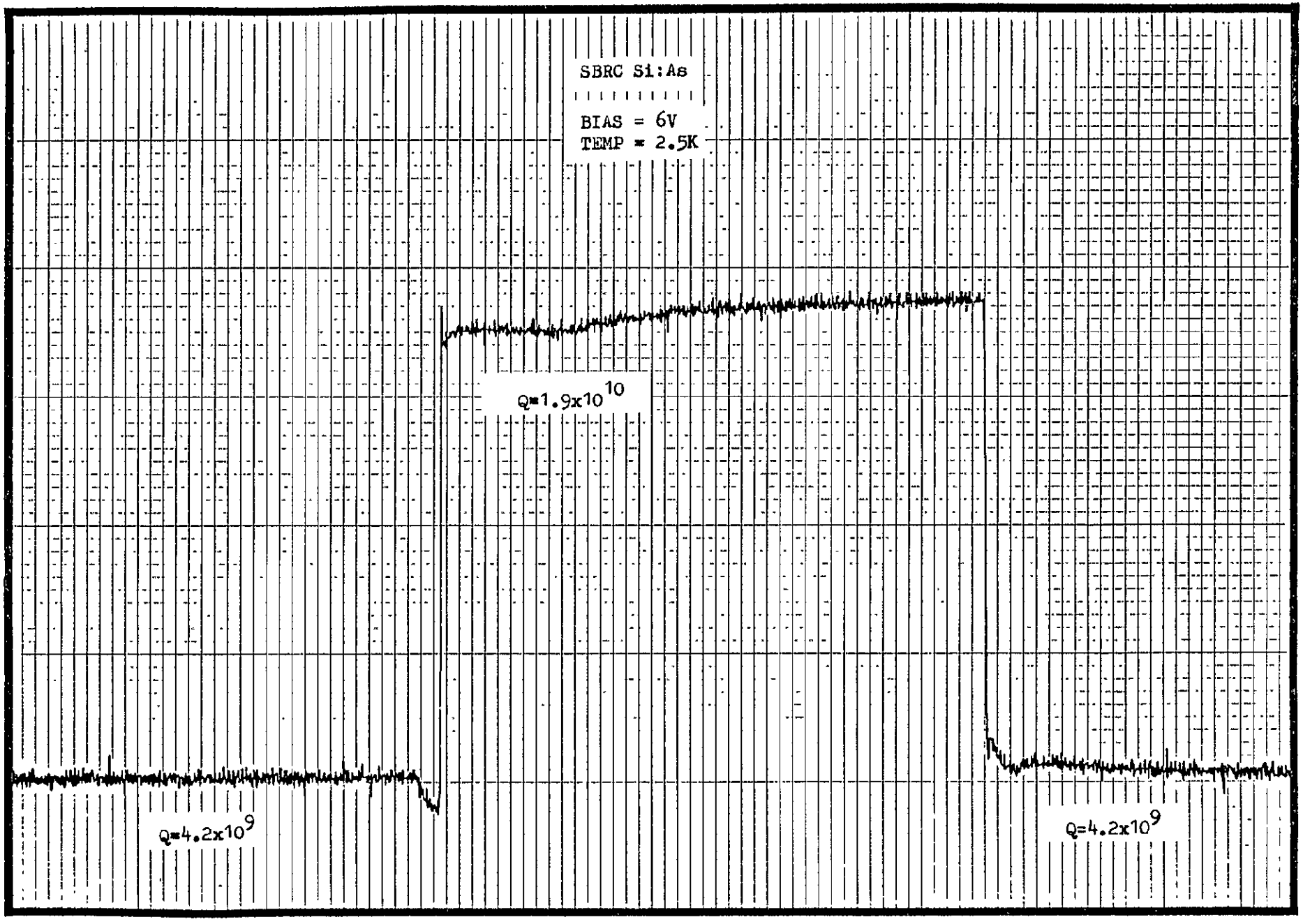

SBRC Si:As
BIAS = 6V
TEMP = 2.5K
Q=1.9x10^10
Q=4.2x10^9
Q=4.2x10^9
OUTPUT (50 mV/IN)
TIME (0.5 SEC/IN)

Figure 73

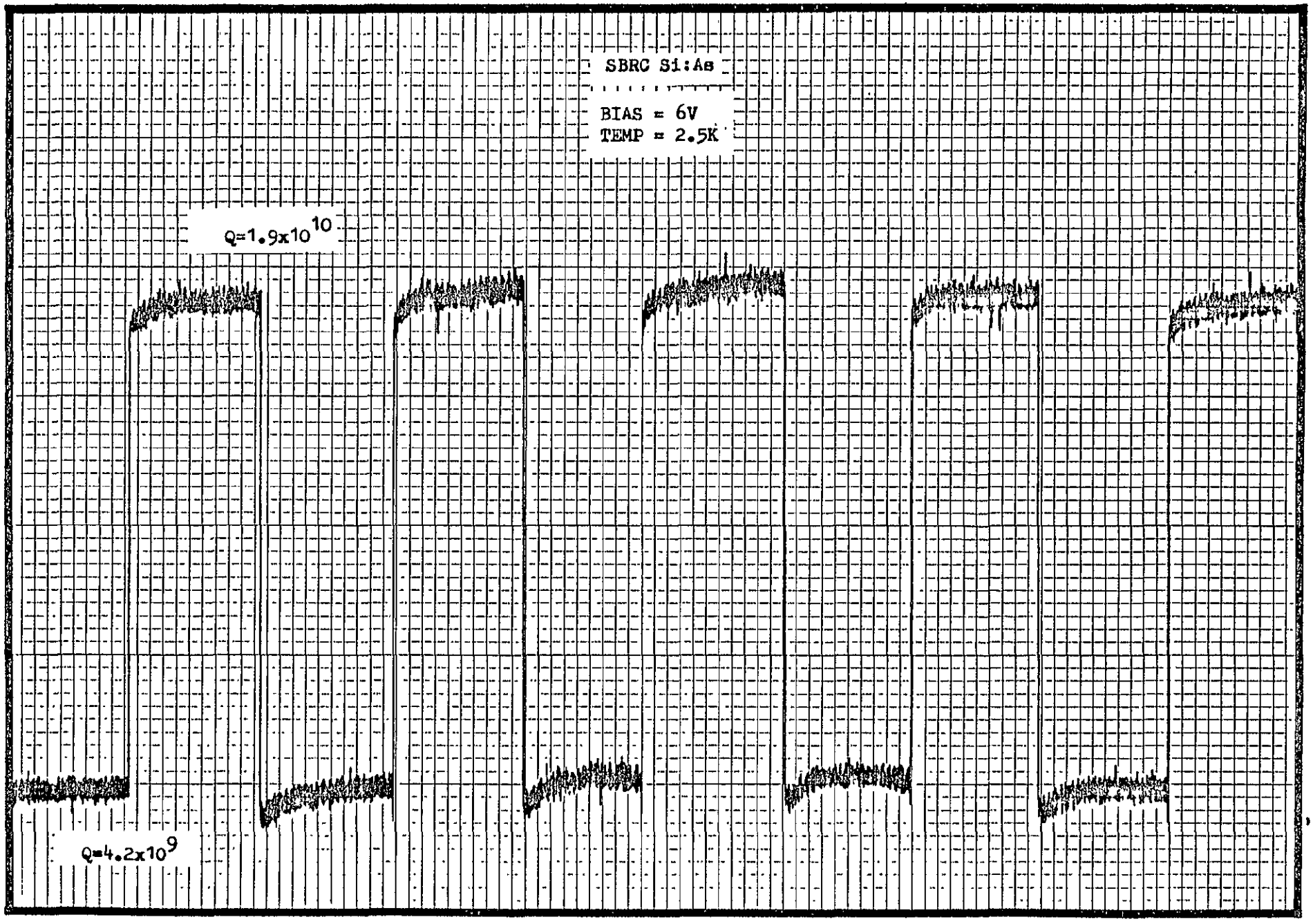

SBRC Si:As
BIAS = 6V
TEMP = 2.5K
Q=1.9x10^10
Q=4.2x10^9
OUTPUT (50 mV/IN)
TIME (100 SEC/IN)

Figure 74

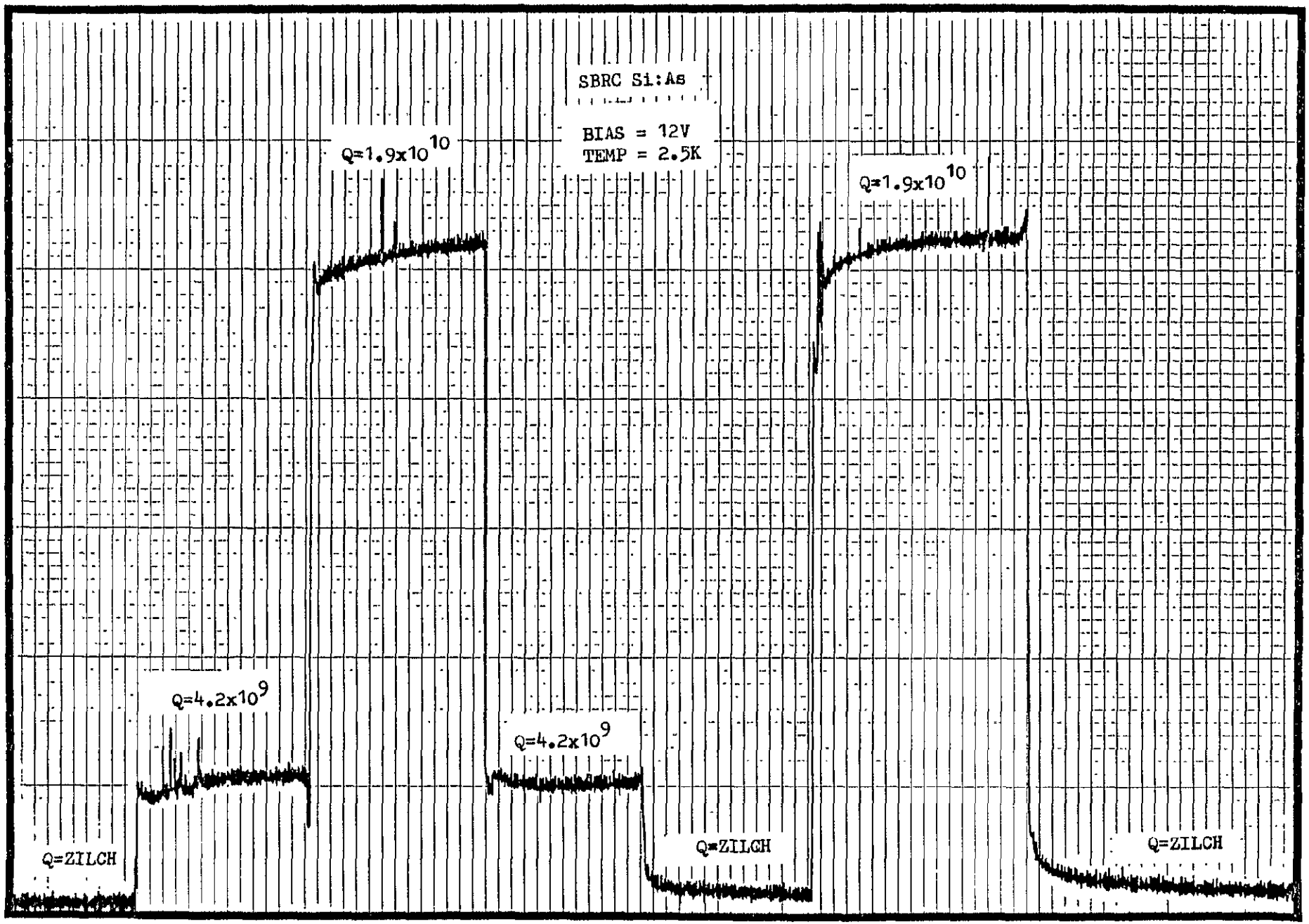

SBRC Si:As
BIAS = 12V
TEMP = 2.5K
Q=1.9x10^10
Q=4.2x10^9
Q=4.2x10^9
Q=1.9x10^10
Q=ZILCH
Q=ZILCH
Q=ZILCH
OUTPUT (100 mV/IN)
TIME (10 SEC/IN)

Figure 75

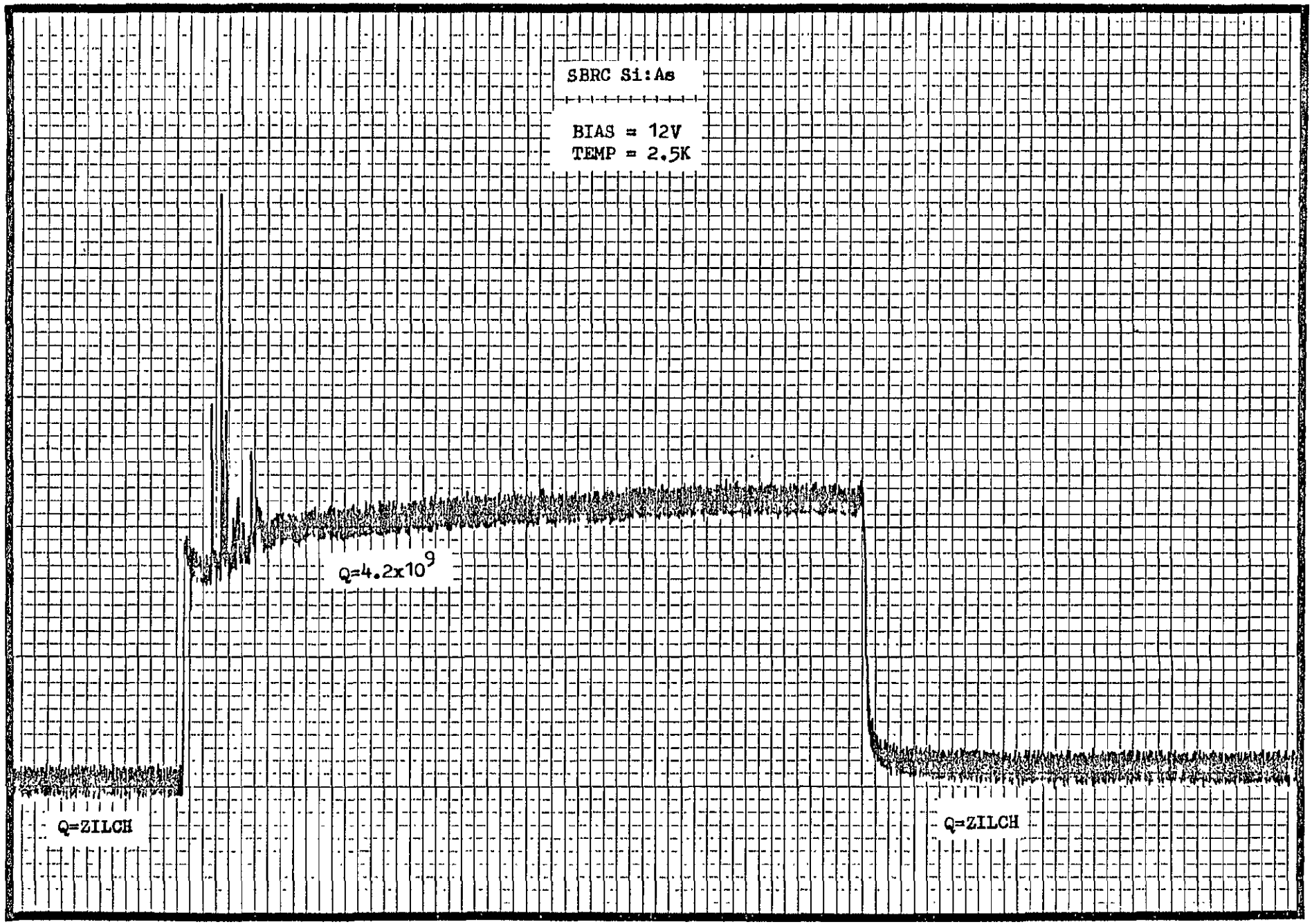

SBRC Si:As
BIAS = 12V
TEMP = 2.5K
Q=4.2x10^9
Q=ZILCH
Q=ZILCH
OUTPUT (50 mV/IN)
TIME (10 SEC/IN)

Figure 76

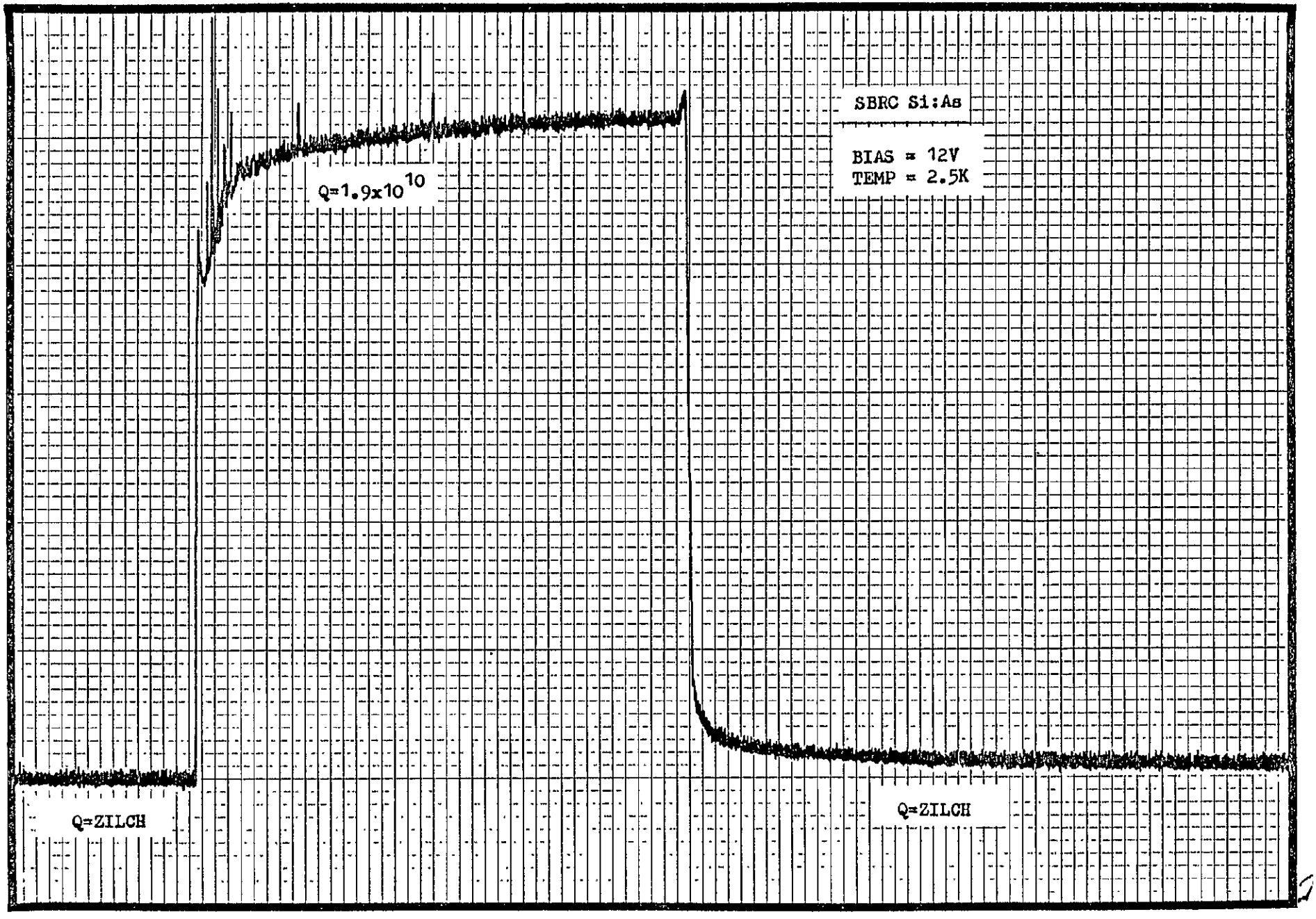

SBRC Si:As
BIAS = 12V
TEMP = 2.5K
Q=1.9x10^10
Q=ZILCH
Q=ZILCH
OUTPUT (100 mV/IN)
TIME (5 SEC/IN)

Figure 77

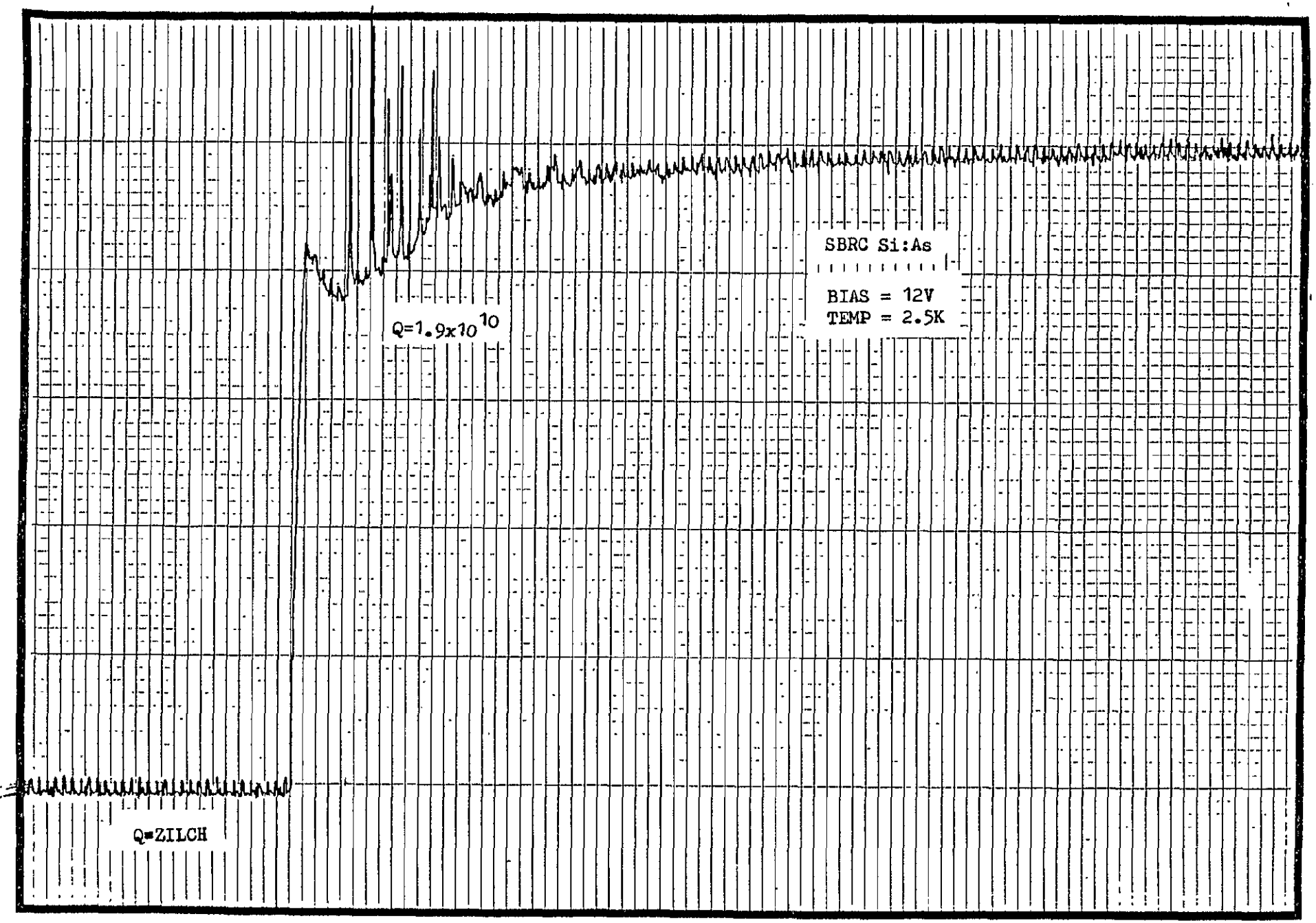

SBRC Si:As
BIAS = 12V
TEMP = 2.5K
Q=1.9x10^10
Q=ZILCH
OUTPUT (100 mV/IN)
TIME (1.0 SEC/IN)

Figure 78

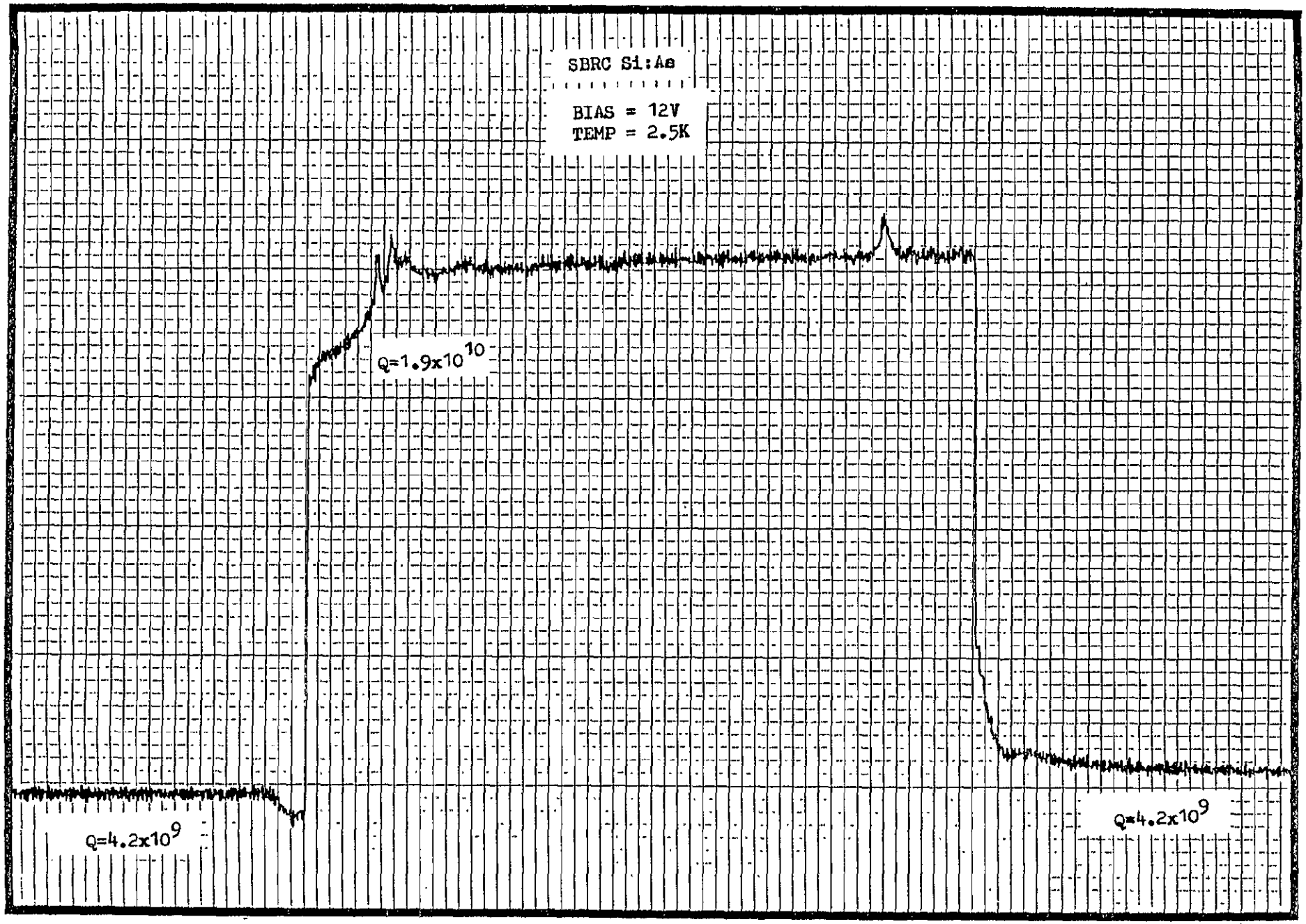

SBRC Si:As
BIAS = 12V
TEMP = 2.5K
Q=1.9x10^10
Q=4.2x10^9
Q=4.2x10^9
OUTPUT (100 mV/IN)
TIME (0.5 SEC/IN)

Figure 79

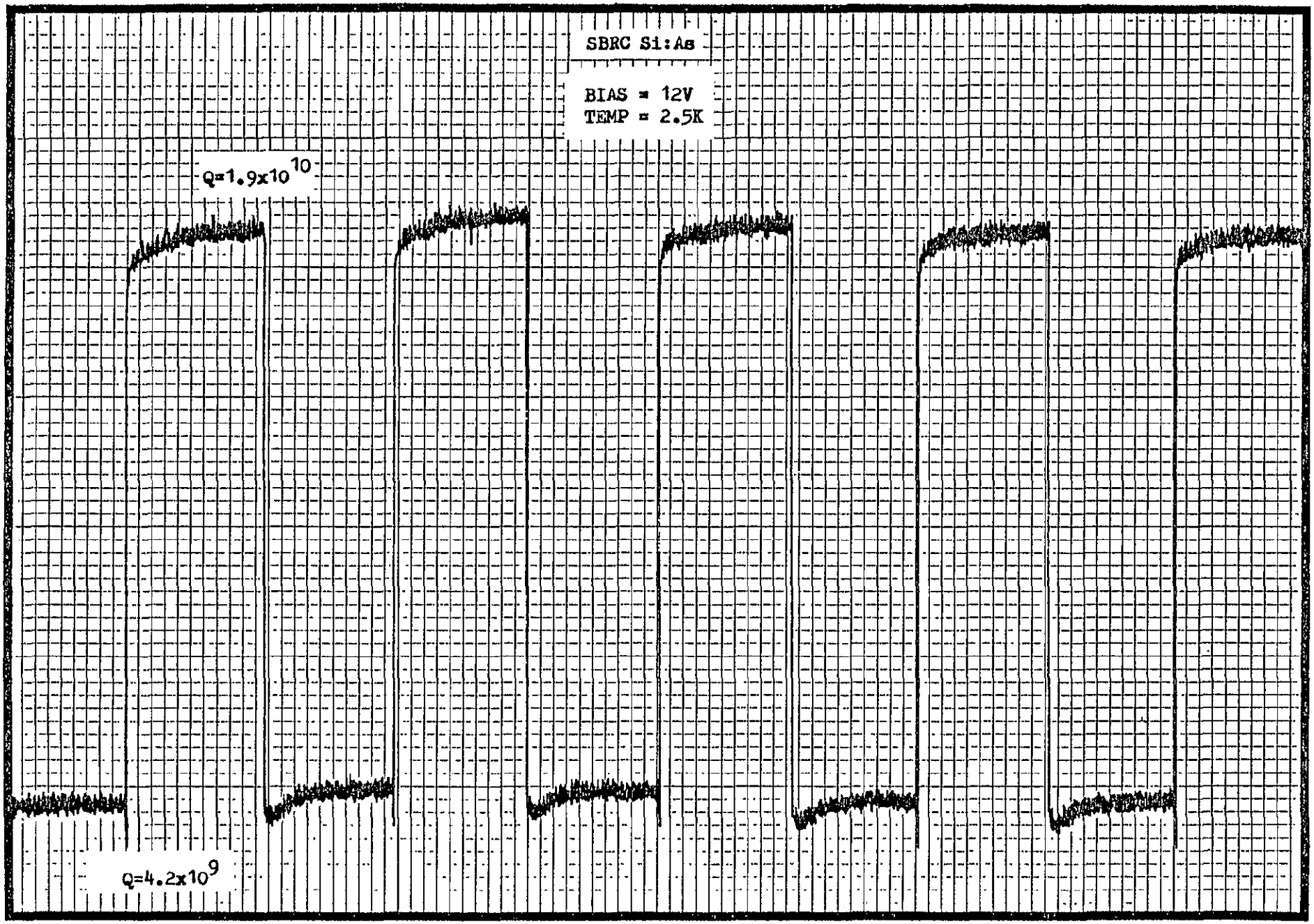

SBRC Si:As
BIAS = 12V
TEMP = 2.5K
Q=1.9x10^10
Q=4.2x10^9
OUTPUT (100 mV/IN)
TIME (100 SEC/IN)

Figure 80

C-2

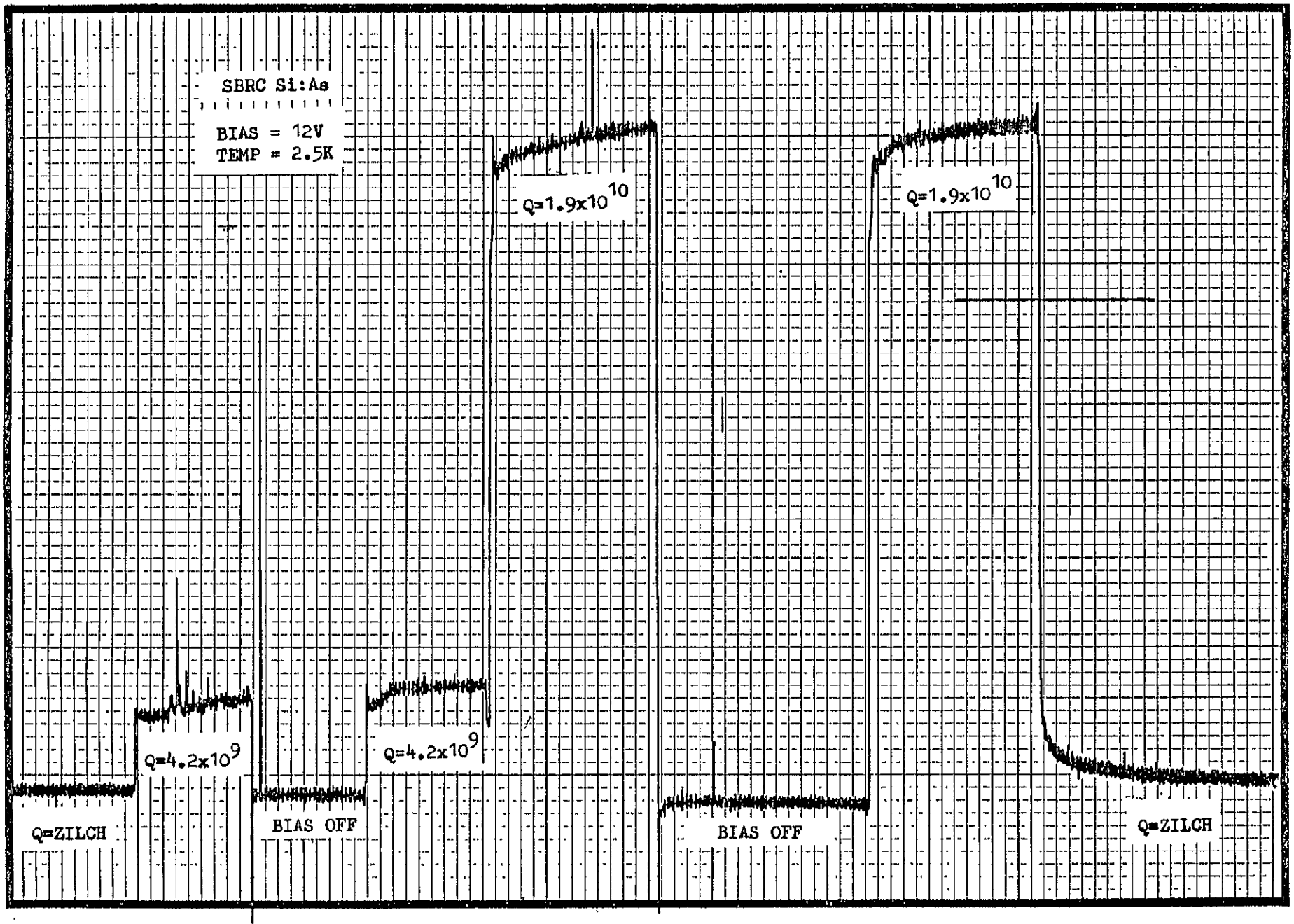

SBRC Si:As
BIAS = 12V
TEMP = 2.5K
Q=1.9x10^10
Q=1.9x10^10
Q=4.2x10^9
Q=4.2x10^9
Q=ZILCH
BIAS OFF
BIAS OFF
Q=ZILCH
OUTPUT (100 mV/IN)
TIME (10 SEC/IN)

Figure 81

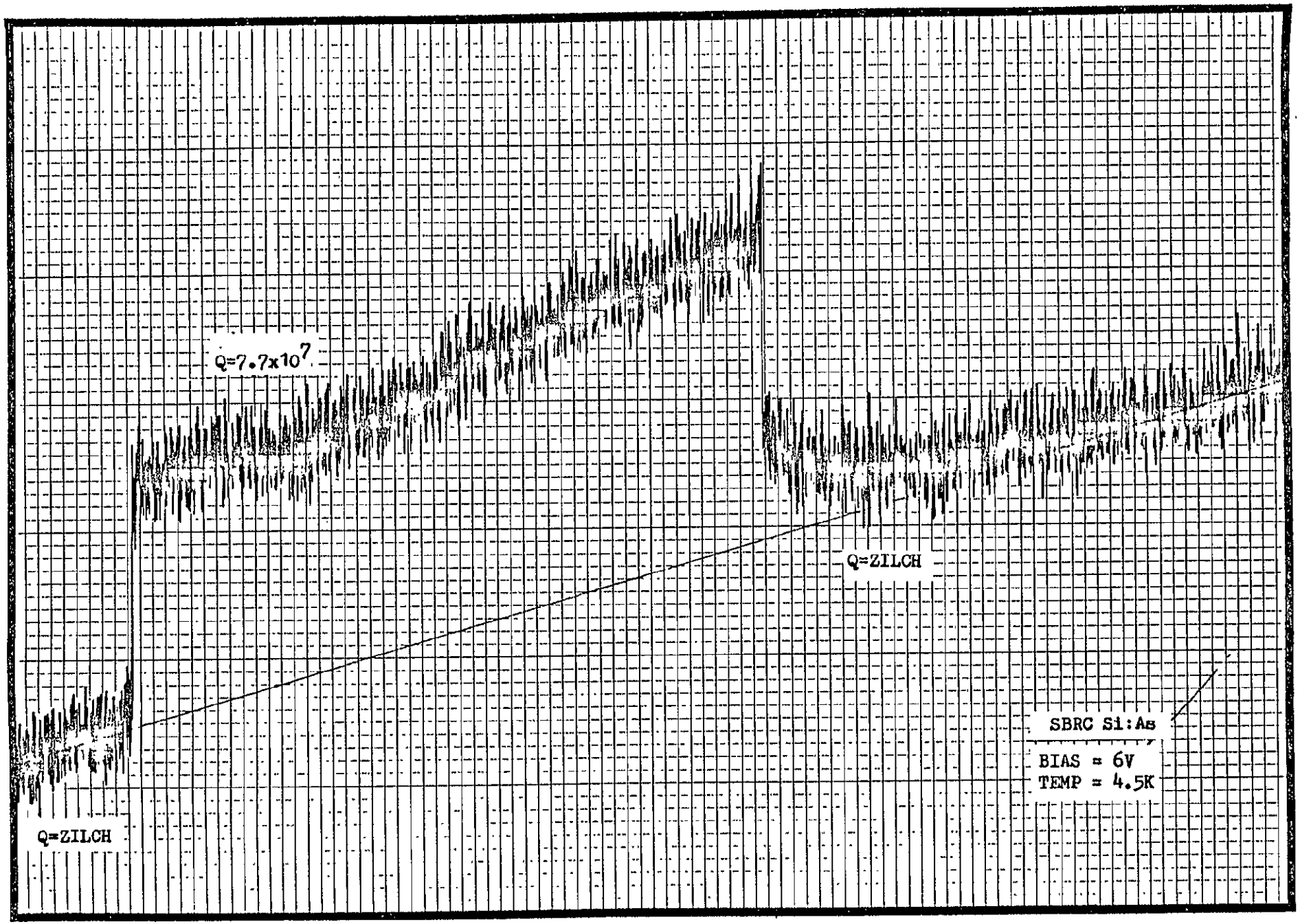

OUTPUT (200uV/IN)
Q=7.7x10^7
Q=ZILCH
Q=ZILCH
SBRC Si:As
BIAS = 6V
TEMP = 4.5K
TIME (50 SEC/IN)

Figure 82

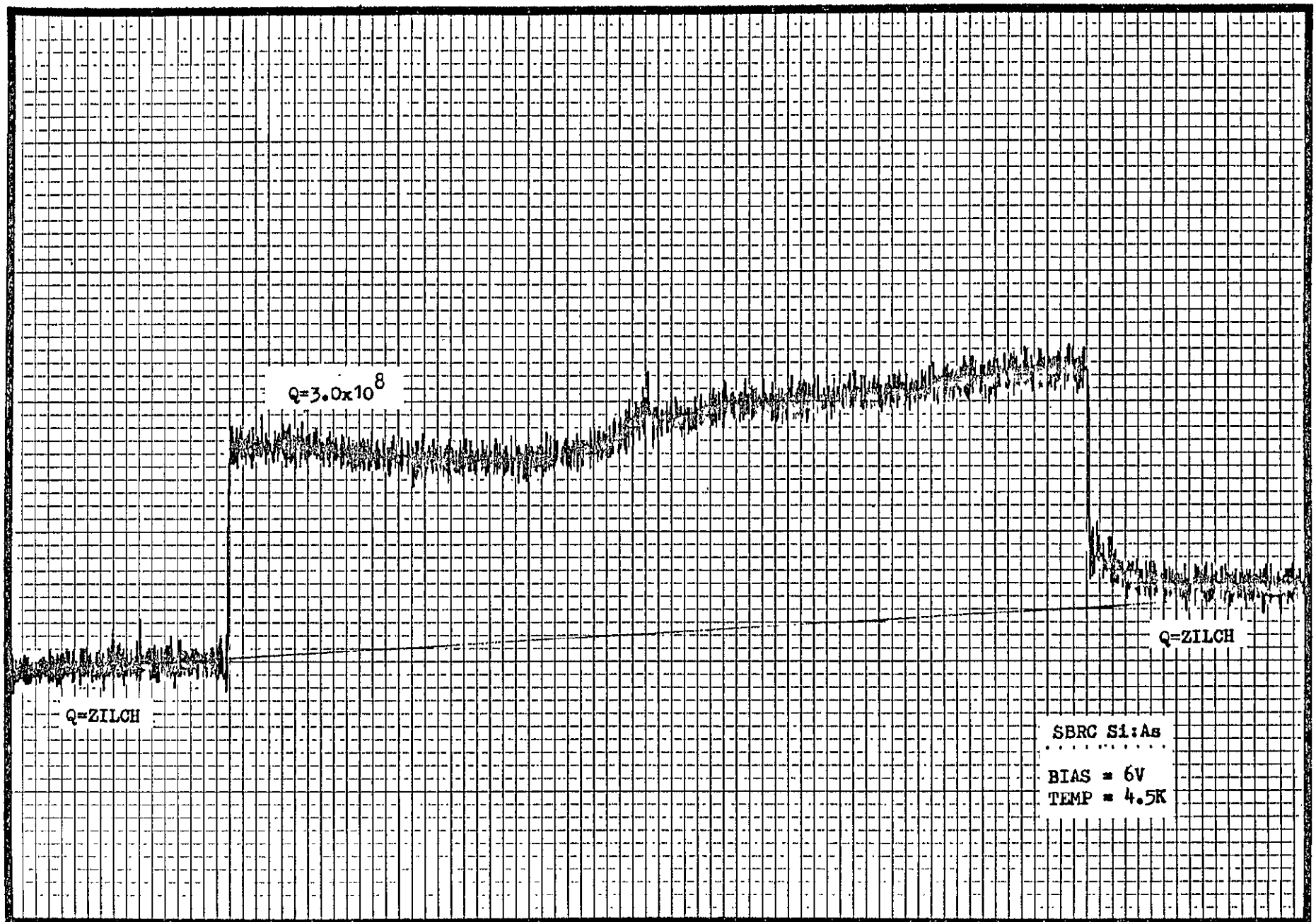

Q=3.0x10^8
Q=ZILCH
Q=ZILCH
SBRC Si:As
BIAS = 6V
TEMP = 4.5K
OUTPUT (500μV/IN)
TIME (20 SEC/IN)

Figure 83

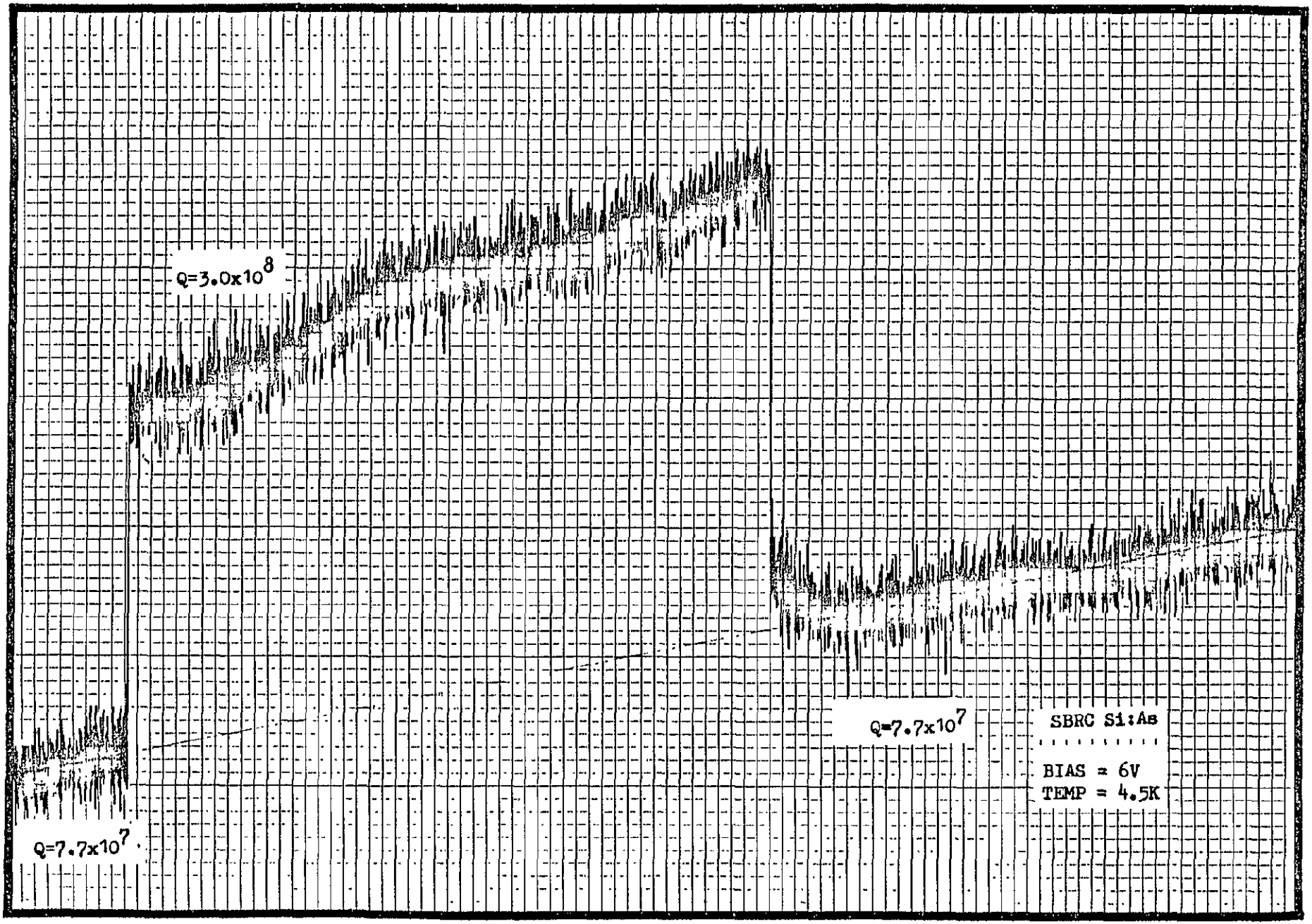

Q=3.0x10^8
Q=7.7x10^7
Q=7.7x10^7
SBRC Si:As
BIAS = 6V
TEMP = 4.5K
OUTPUT (200μV/IN)
TIME (20 SEC/IN)

Figure 84

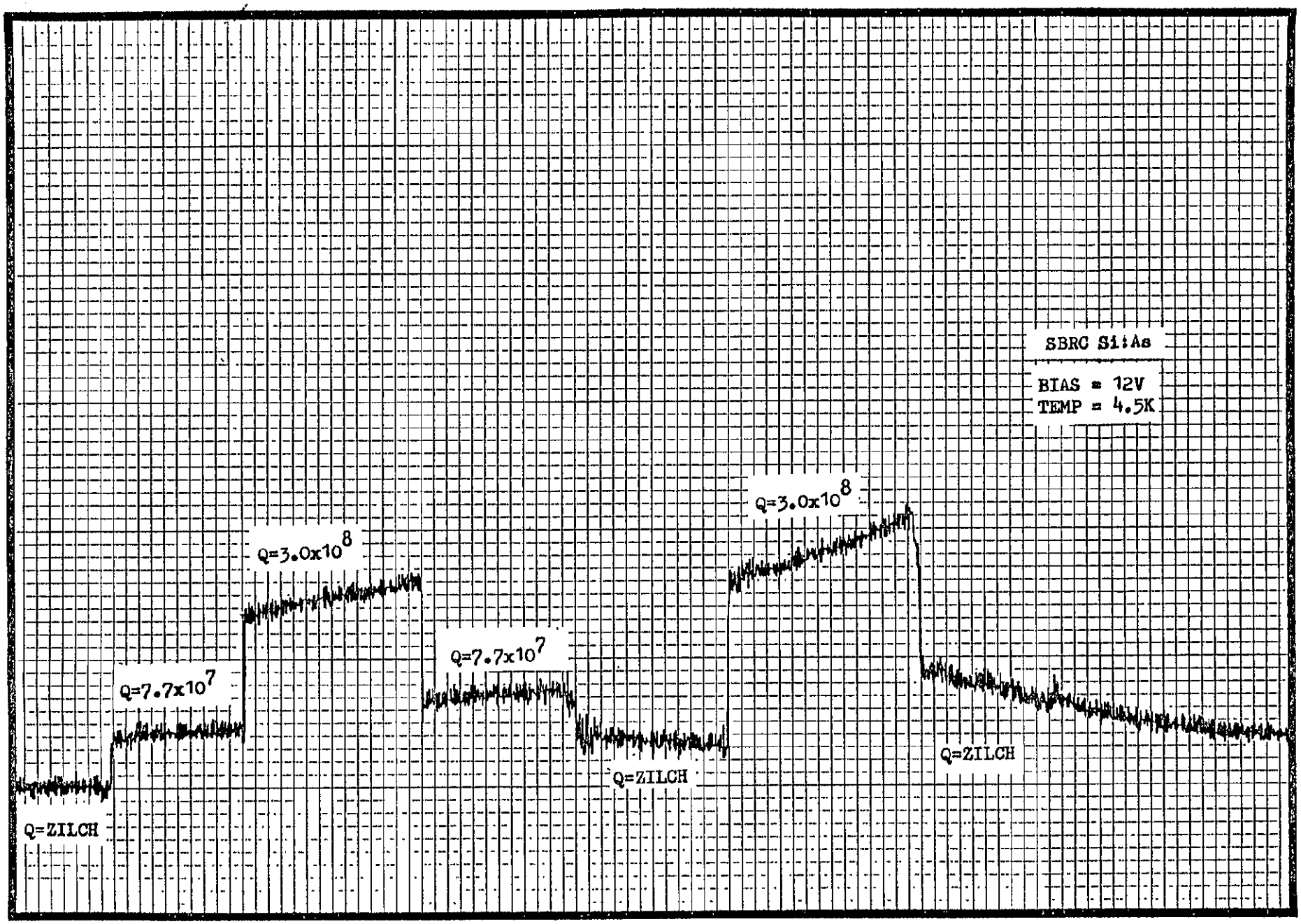

SBRC Si:As
BIAS = 12V
TEMP = 4.5K
Q=3.0x10^8
Q=7.7x10^7
Q=3.0x10^8
Q=7.7x10^7
Q=ZILCH
Q=ZILCH
Q=ZILCH
OUTPUT (1 mV/IN)
TIME (10 SEC/IN)

Figure 85

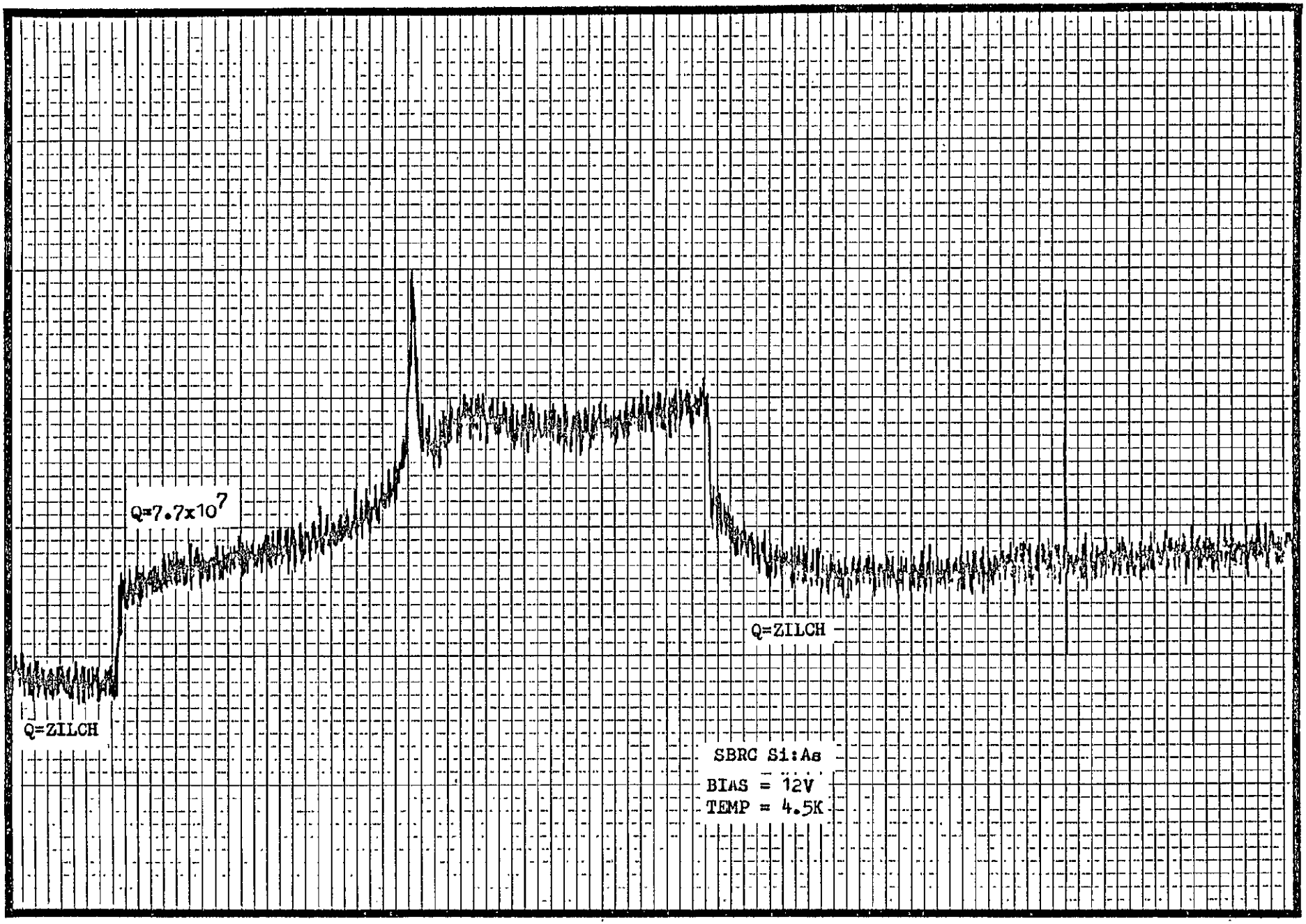

Q=7.7x10^7
Q=ZILCH
Q=ZILCH
SBRC Si:As
BIAS = 12V
TEMP = 4.5K
OUTPUT (500 μV/IN)
TIME (50 SEC/IN)

Figure 86

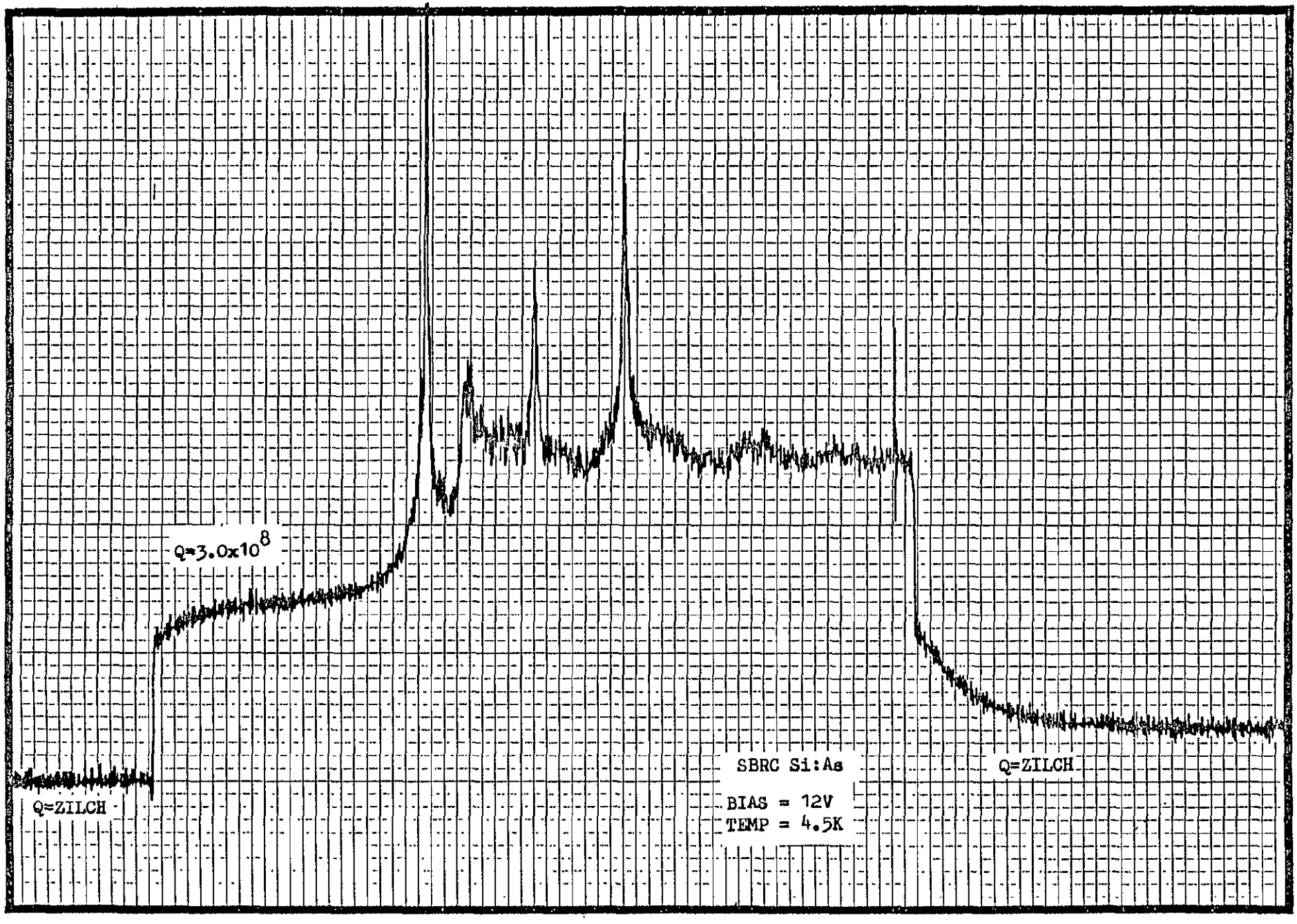

OUTPUT (1 mV/IN)
Q=3.0x10^8
Q=ZILCH
Q=ZILCH
SBRC Si:As
BIAS = 12V
TEMP = 4.5K
TIME (20 SEC/IN)

Figure 87

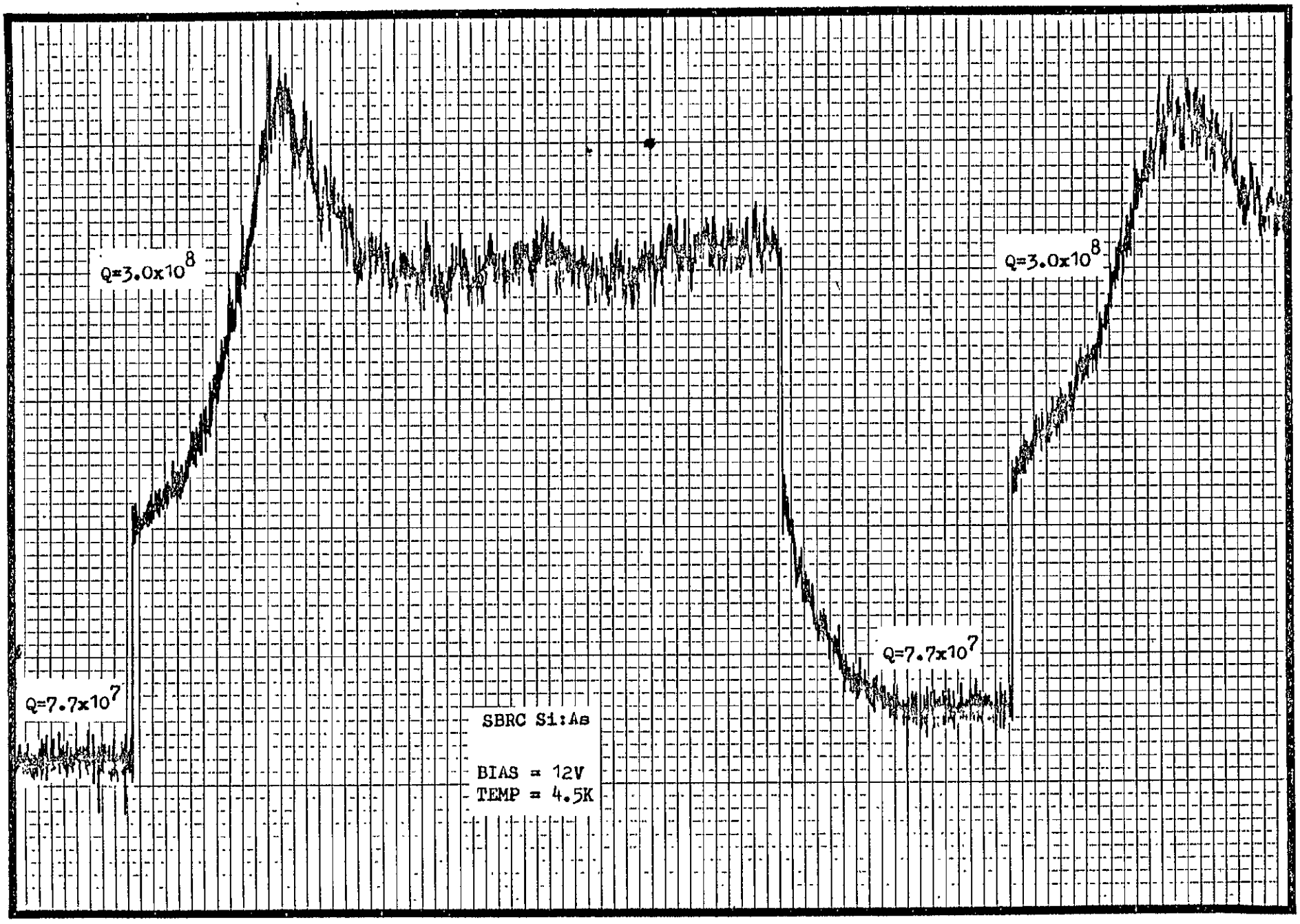

Q=3.0x10^8
Q=3.0x10^8
Q=7.7x10^7
Q=7.7x10^7
SBRC Si:As
BIAS = 12V
TEMP = 4.5K
OUTPUT (500mV/IN)
TIME (20 SEC/IN)

Figure 88

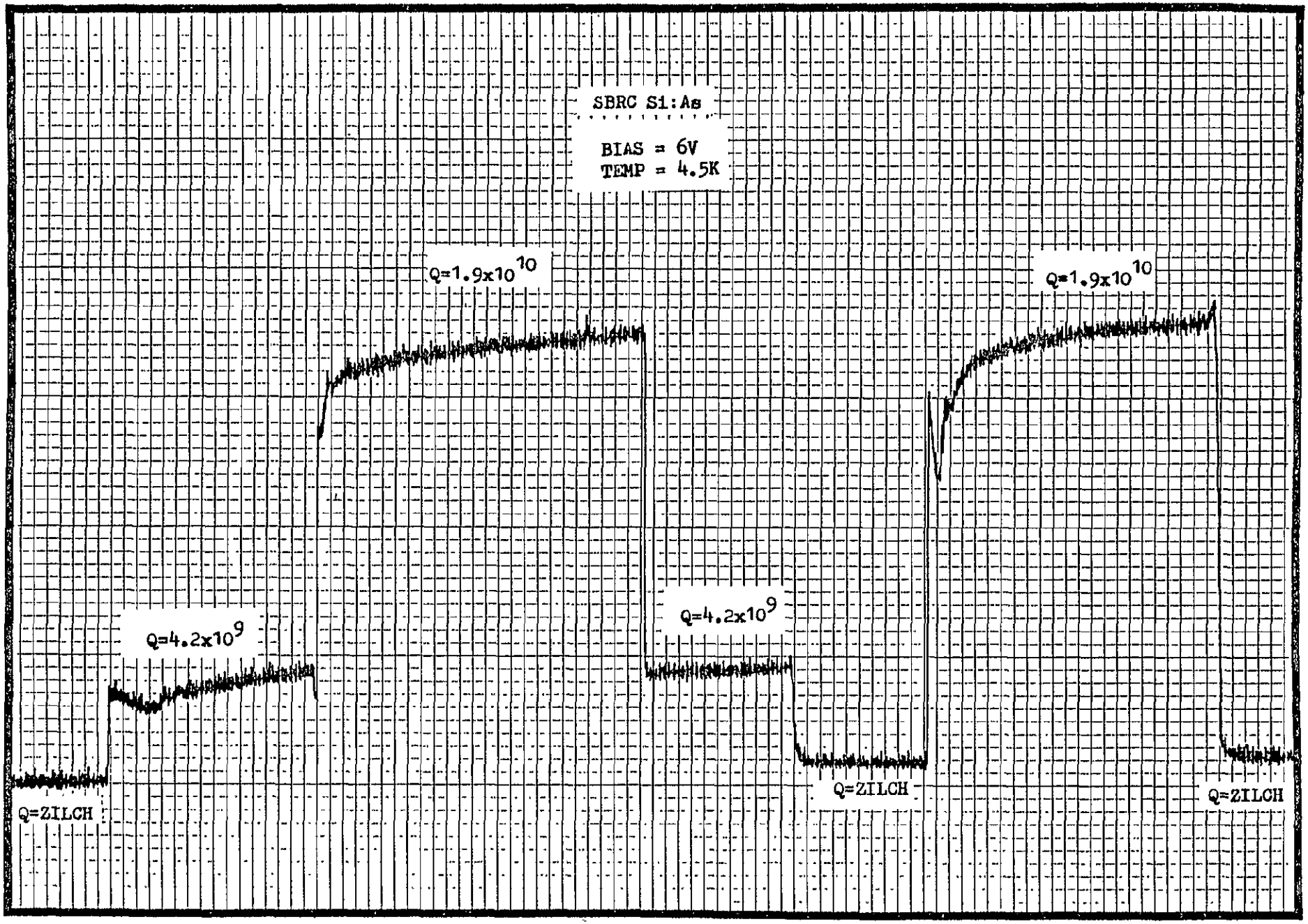

SBRC S1:As
BIAS = 6V
TEMP = 4.5K
Q=1.9x10^10
Q=1.9x10^10
Q=4.2x10^9
Q=4.2x10^9
Q=ZILCH
Q=ZILCH
Q=ZILCH
OUTPUT (20 mV/IN)
TIME (10 SEC/IN)

Figure 89

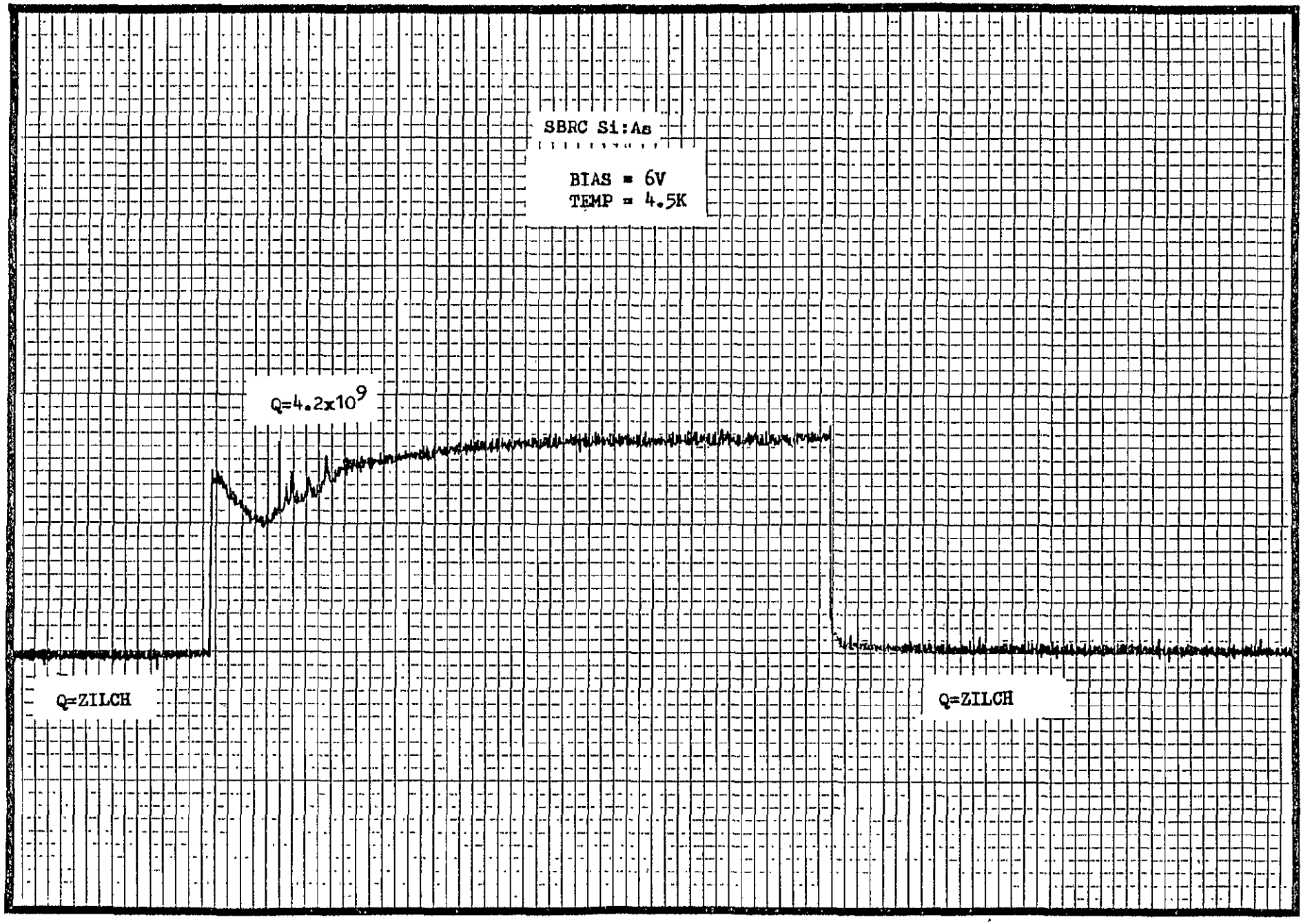

SBRC Si:As
BIAS = 6V
TEMP = 4.5K
Q=4.2x10^9
Q=ZILCH
Q=ZILCH
OUTPUT (10 mV/IN)
TIME (10 SEC/IN)

Figure 90

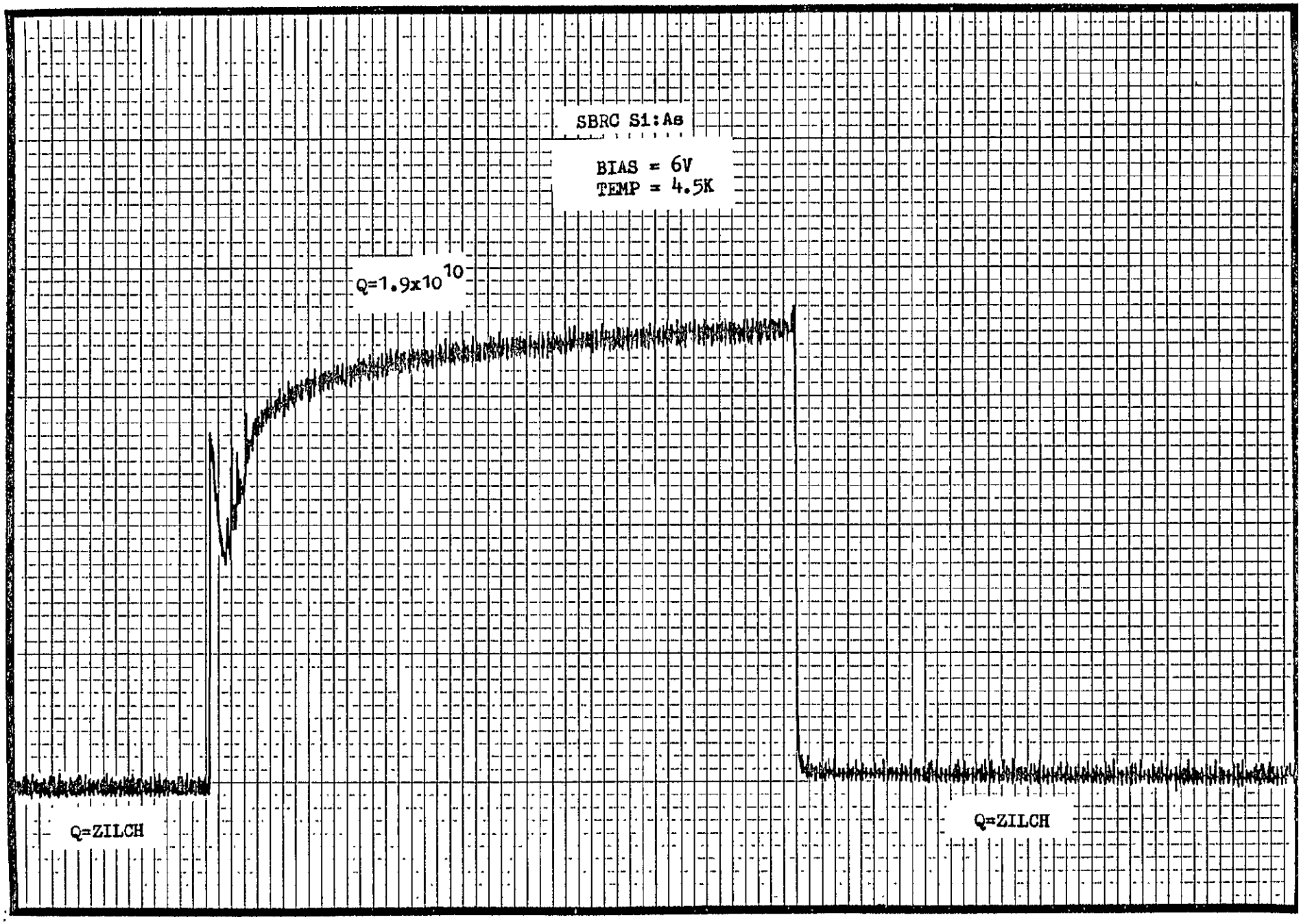

SBRC S1:As
BIAS = 6V
TEMP = 4.5K
Q=1.9x10^10
Q=ZILCH
Q=ZILCH
OUTPUT (20 mV/IN)
TIME (10 SEC/IN)

Figure 91

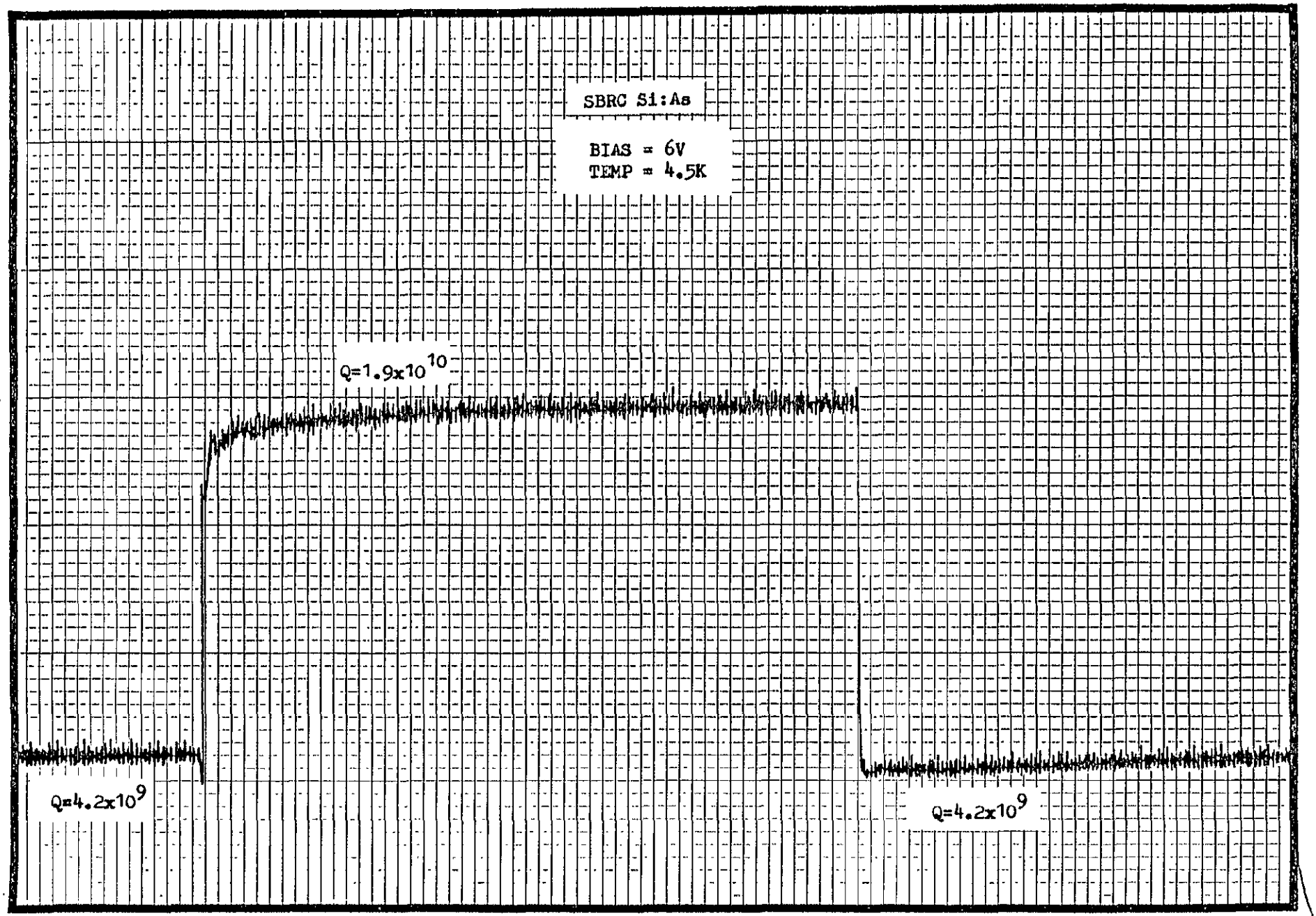

SBRC Si:As
BIAS = 6V
TEMP = 4.5K
Q=1.9x10^10
Q=4.2x10^9
Q=4.2x10^9
OUTPUT (20 mV/IN)
TIME (10 SEC/IN)

Figure 92

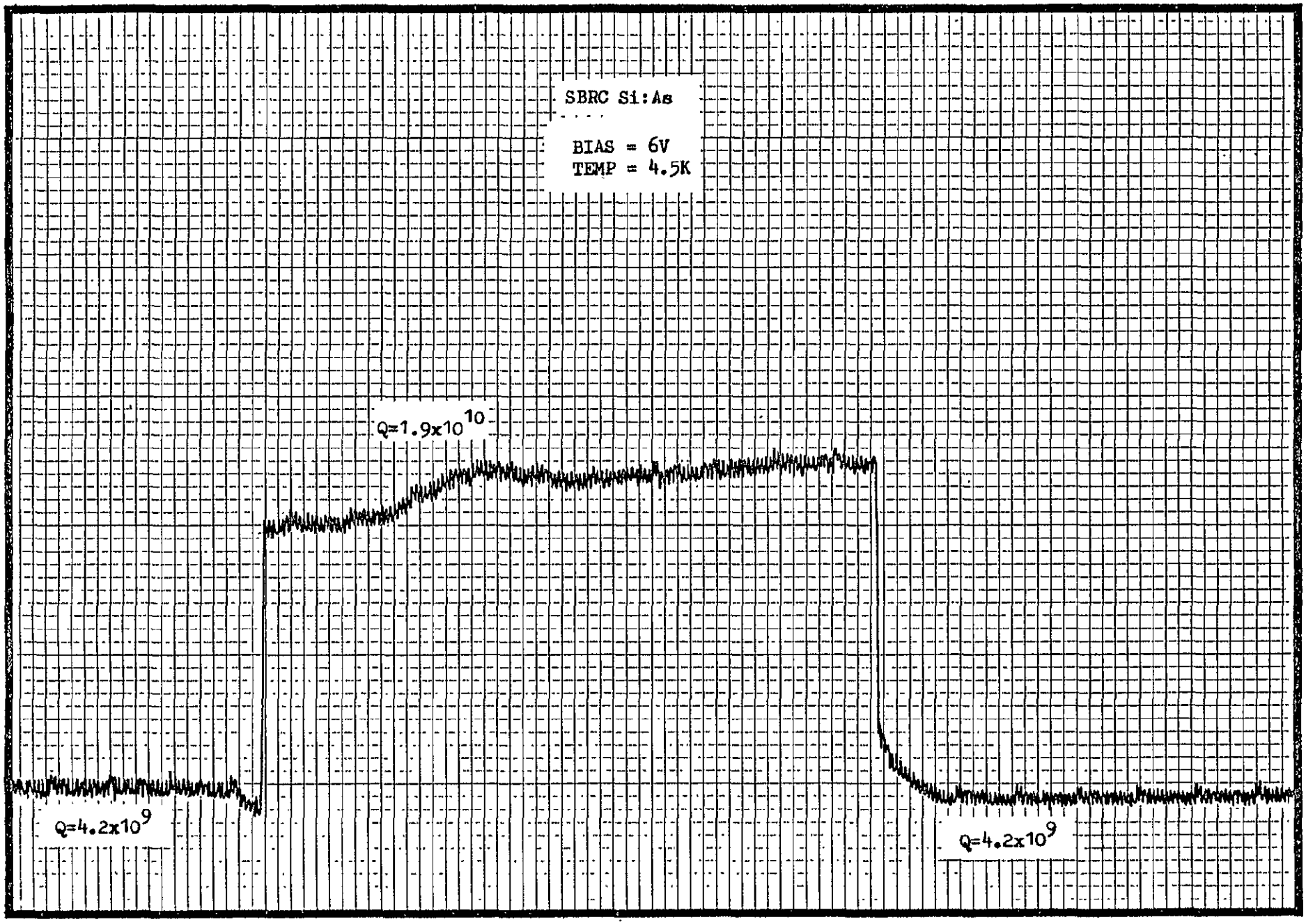

SBRC Si:As
BIAS = 6V
TEMP = 4.5K
Q=1.9x10^10
Q=4.2x10^9
Q=4.2x10^9
OUTPUT (20 mV/IN)
TIME (0.5 SEC/IN)

Figure 93

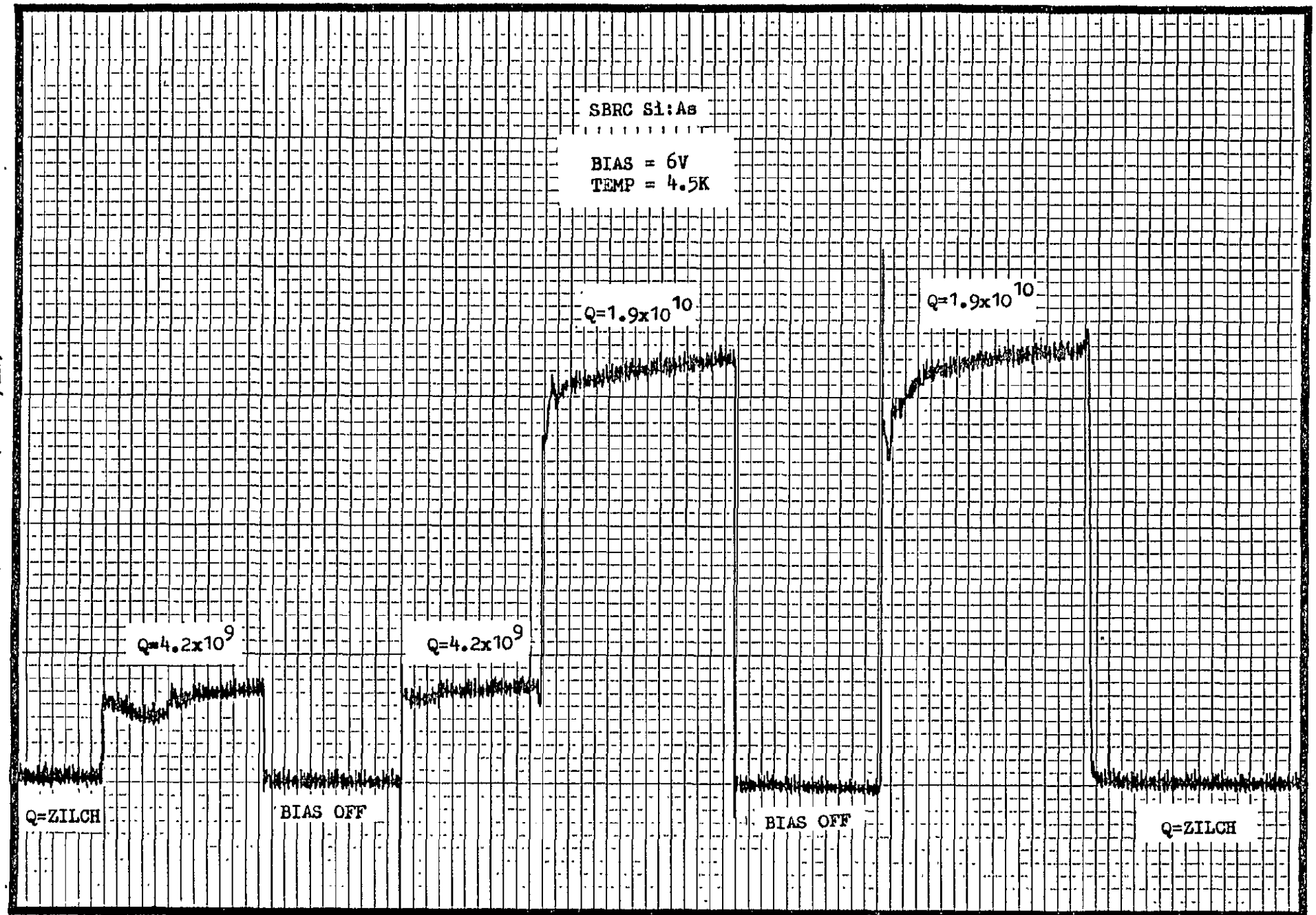

SBRC Si:As
BIAS = 6V
TEMP = 4.5K
Q=1.9x10^10
Q=1.9x10^10
Q=4.2x10^9
Q=4.2x10^9
Q=ZILCH
BIAS OFF
BIAS OFF
Q=ZILCH
OUTPUT (20 mV/IN)
TIME (10 SEC/IN)

Figure 94

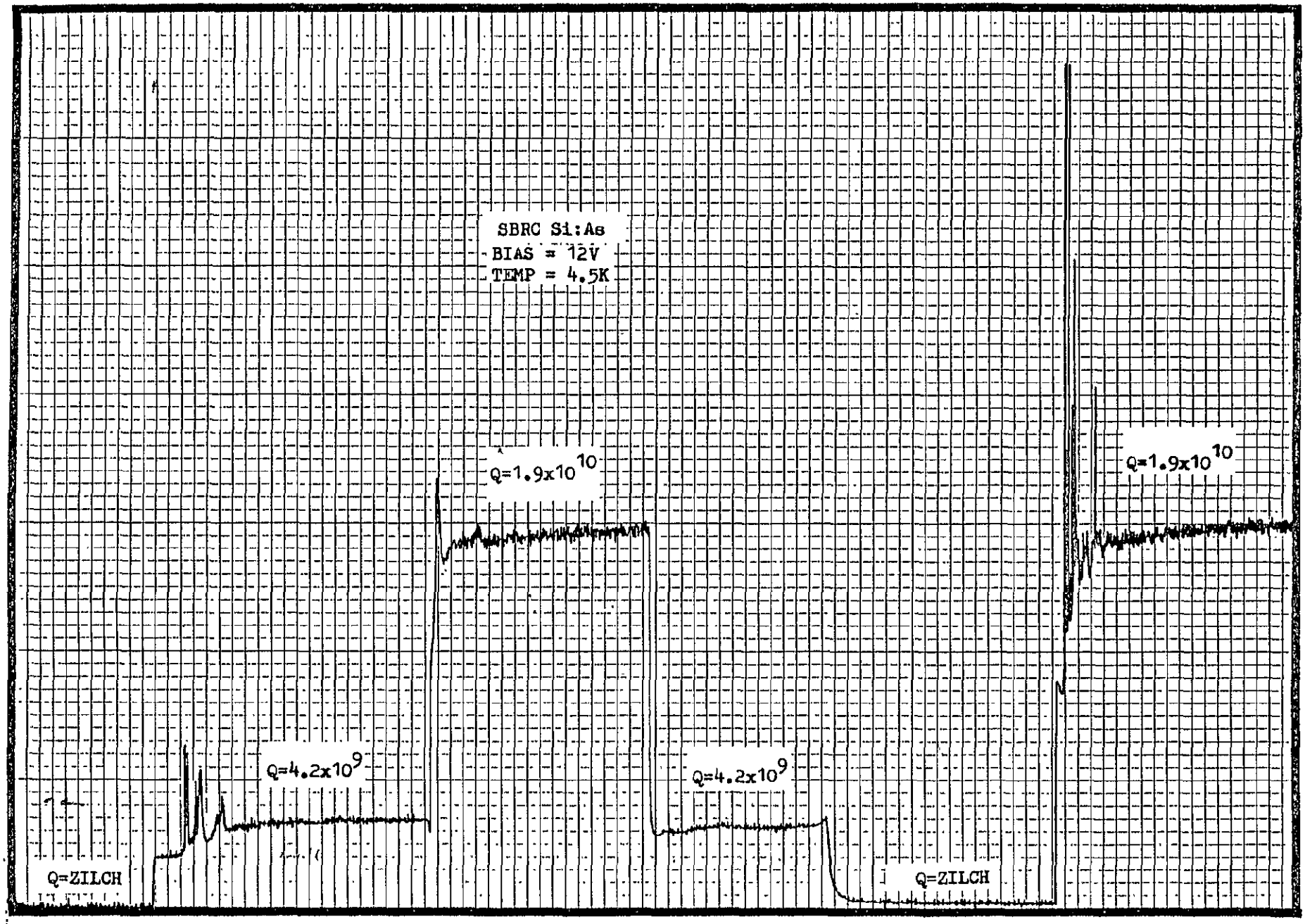

SBRC Si:As
BIAS = 12V
TEMP = 4.5K
Q=1.9x10^10
Q=1.9x10^10
Q=4.2x10^9
Q=4.2x10^9
Q=ZILCH
Q=ZILCH
OUTPUT (50 mV/IN)
TIME (10 SEC/IN)

Figure 95

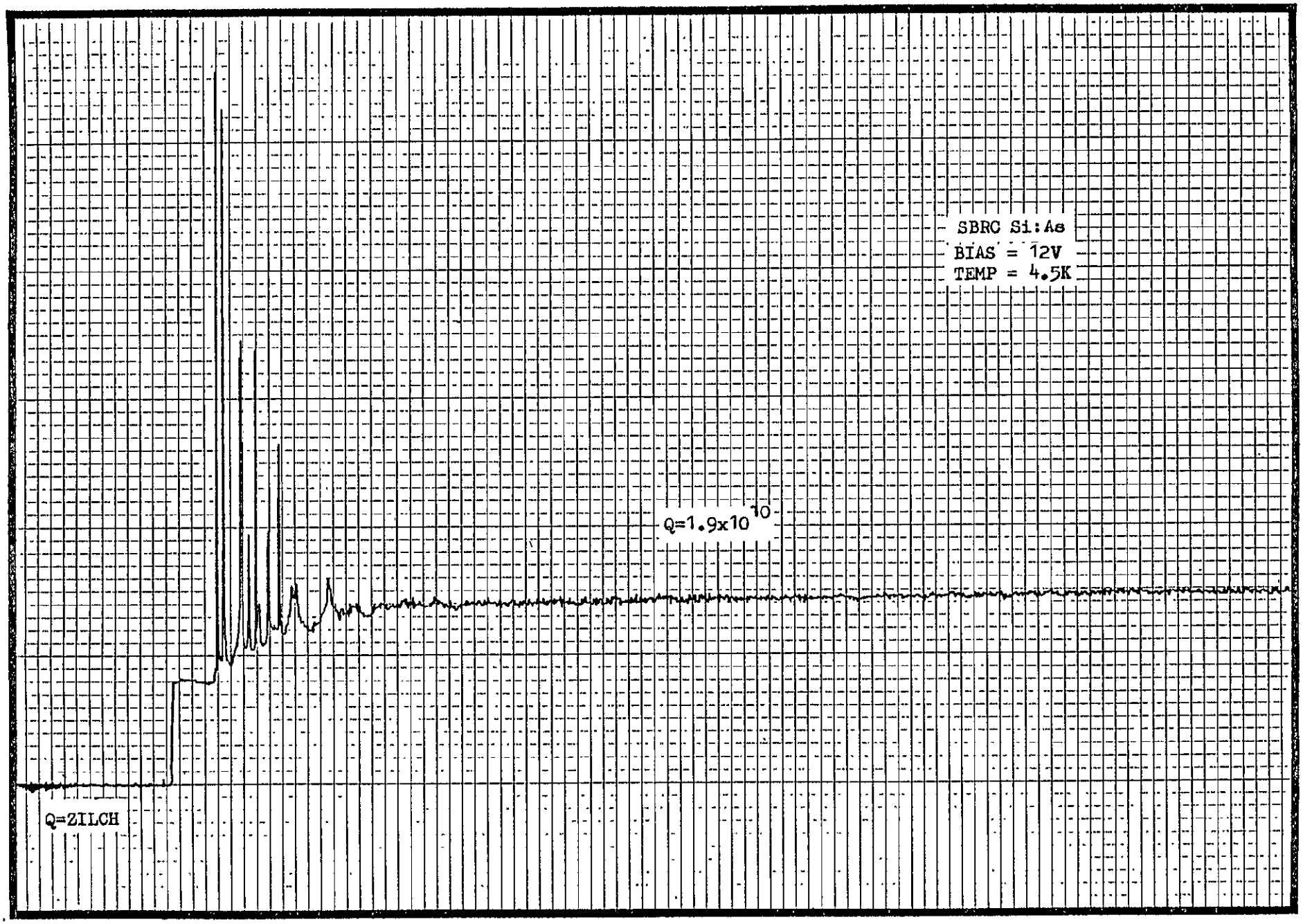

SBRC Si:As
BIAS = 12V
TEMP = 4.5K
Q=1.9x10^10
Q=ZILCH
OUTPUT (100mV/IN)
TIME (2 SEC/IN)

Figure 96

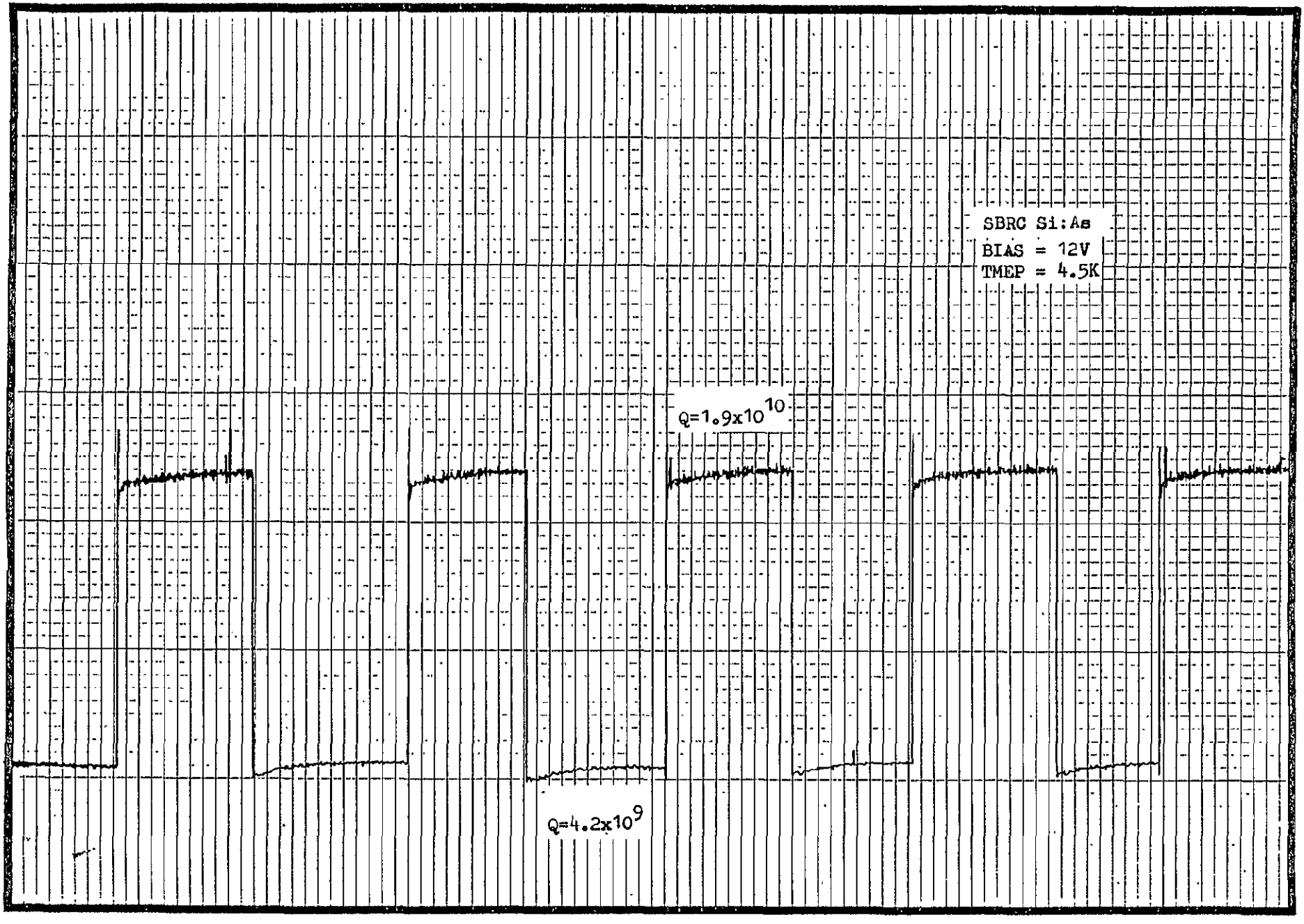

SBRC Si:As
BIAS = 12V
TMEP = 4.5K
Q=1.9x10^10
Q=4.2x10^9
OUTPUT (50 mV/IN)
TIME (100 SEC/IN)

Figure 97

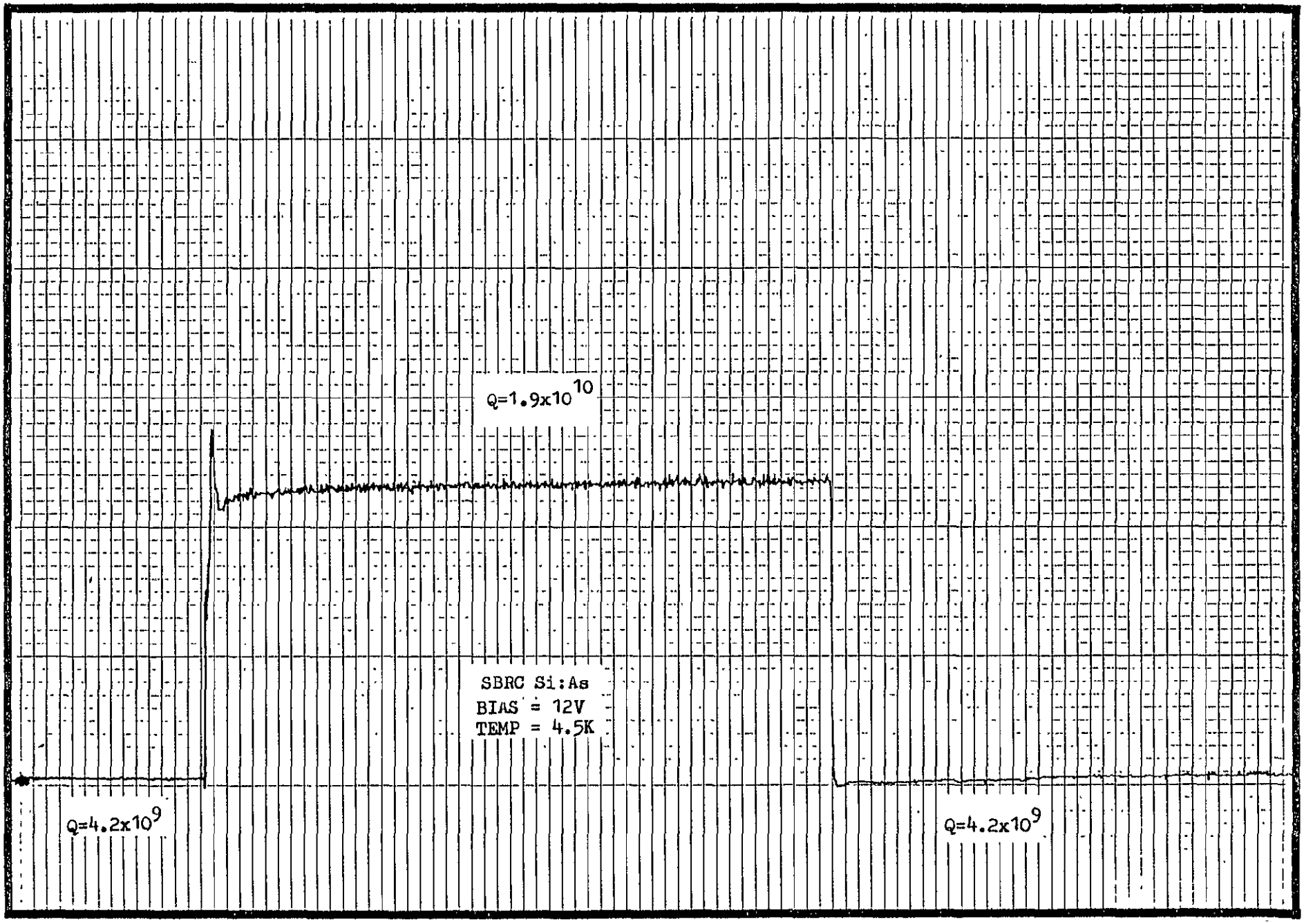

OUTPUT (50 mV/IN)
Q=1.9x10^10
SBRC Si:As
BIAS = 12V
TEMP = 4.5K
Q=4.2x10^9
Q=4.2x10^9
TIME (10/SEC/IN)

Figure 98

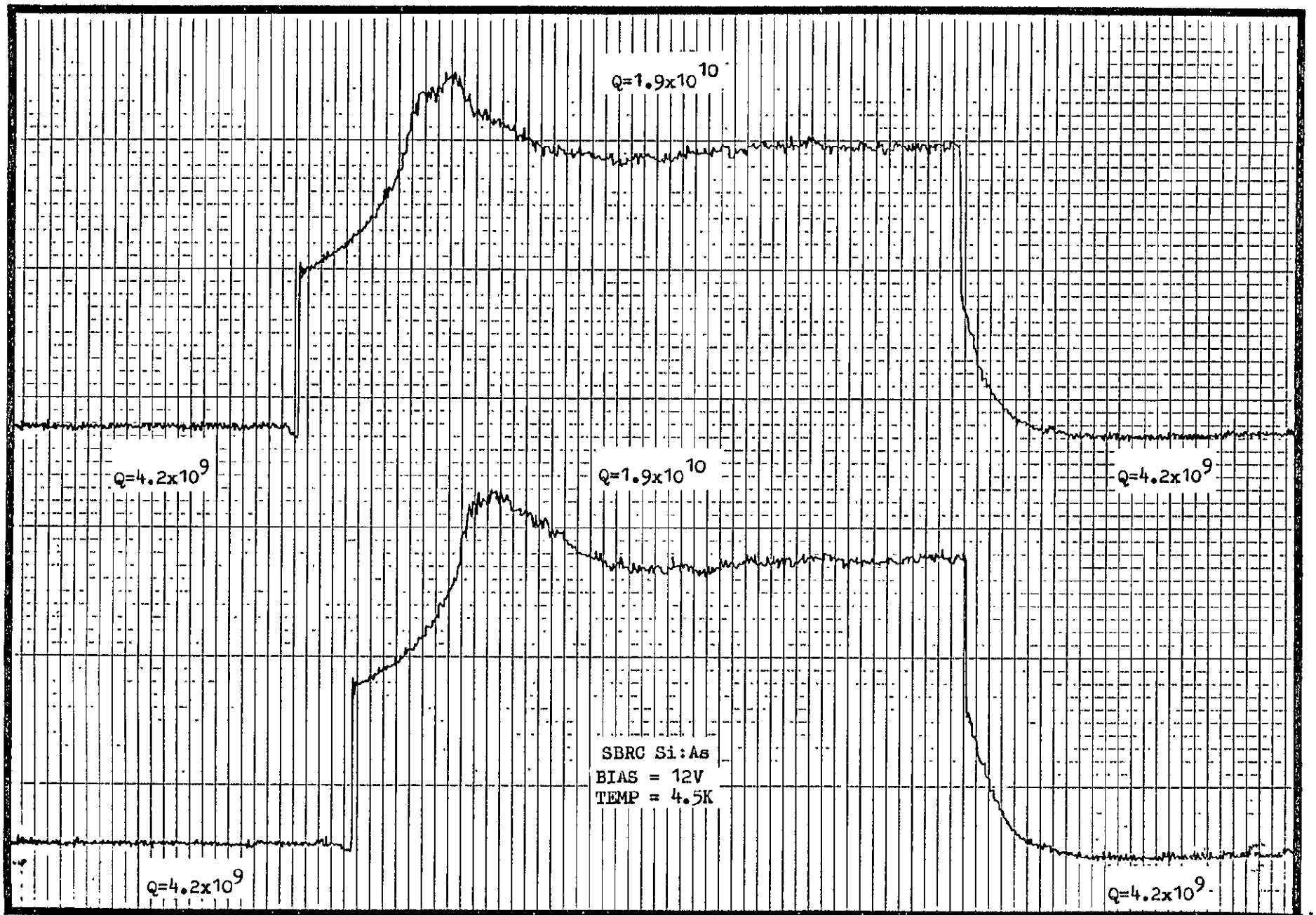

Q=1.9x10^10
Q=4.2x10^9
Q=1.9x10^10
Q=4.2x10^9
SBRC Si:As
BIAS = 12V
TEMP = 4.5K
Q=4.2x10^9
Q=4.2x10^9
OUTPUT (50 mV/IN)
TIME (0.5 SEC/IN)

Figure 99

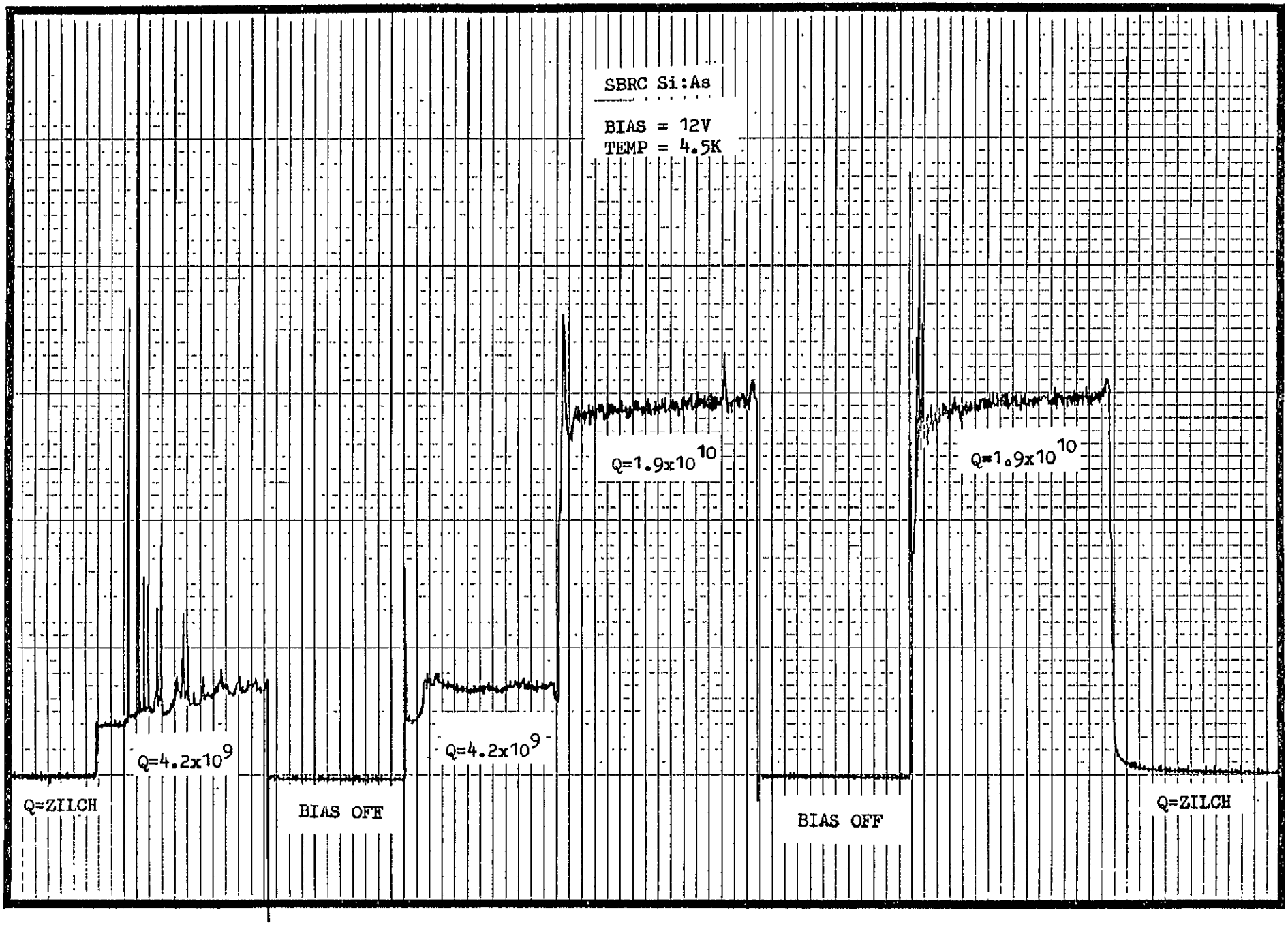

SBRC Si:As
BIAS = 12V
TEMP = 4.5K
OUTPUT (50 mV/IN)
Q=ZILCH
Q=4.2x10^9
BIAS OFF
Q=4.2x10^9
Q=1.9x10^10
BIAS OFF
Q=1.9x10^10
Q=ZILCH
TIME (10 SEC/IN)

Figure 100

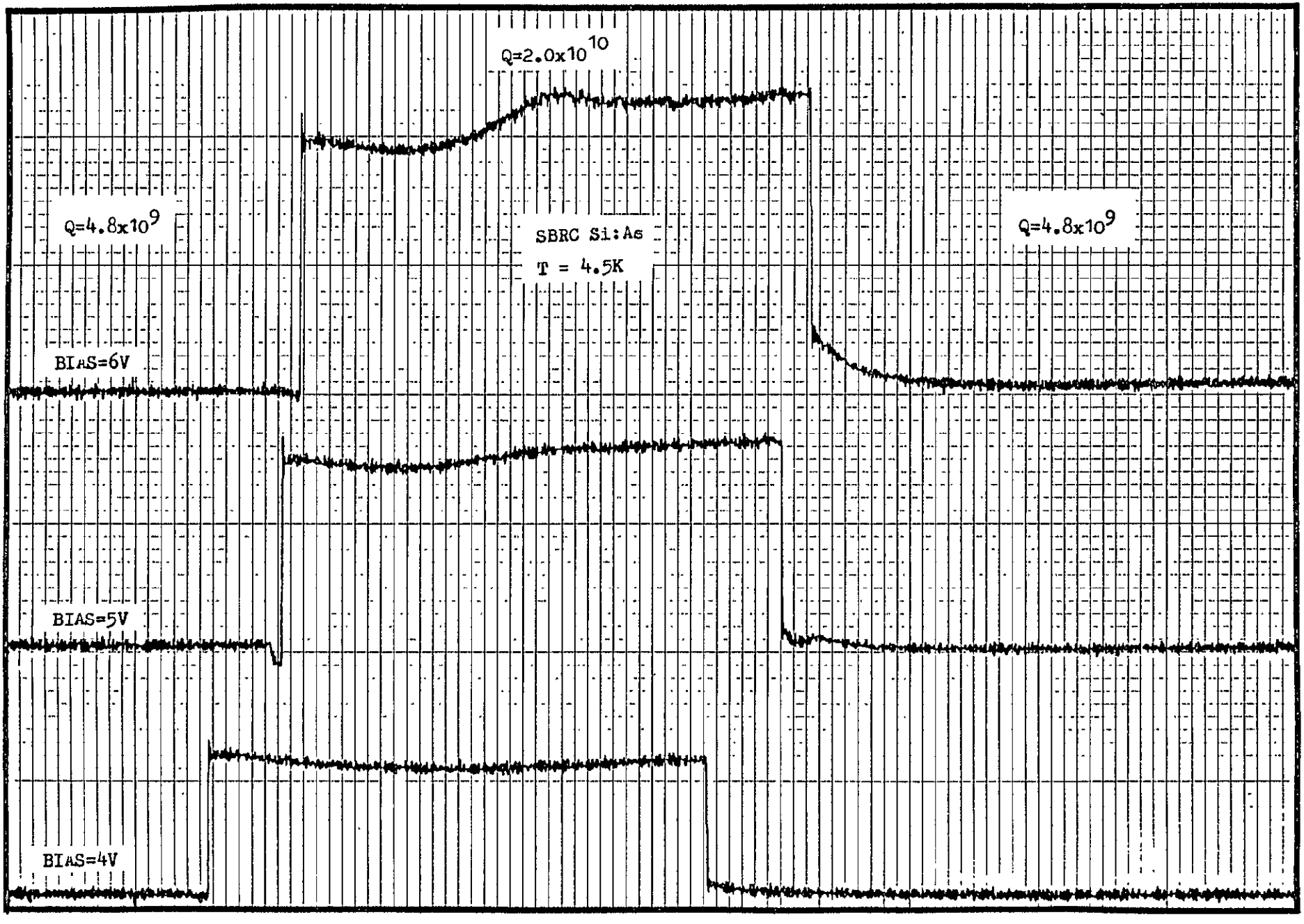

Q=2.0x10^10
Q=4.8x10^9
SBRC Si:As
T = 4.5K
Q=4.8x10^9
BIAS=6V
BIAS=5V
BIAS=4V
DETECTOR OUTPUT (20 mV/IN)
TIME (0.5 SEC/IN)

Figure 101

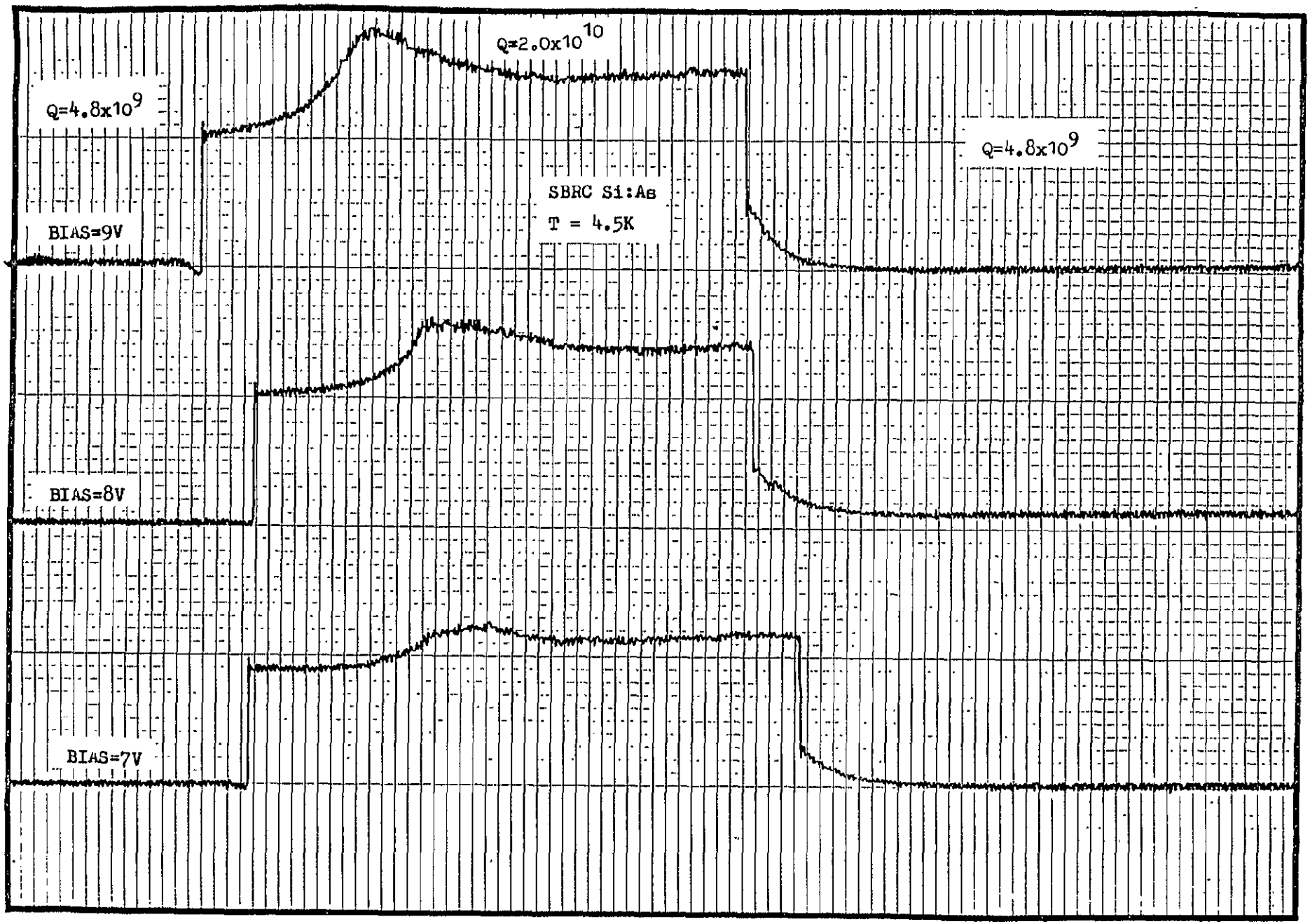

Q=2.0x10^10
Q=4.8x10^9
Q=4.8x10^9
SBRC Si:As
T = 4.5K
BIAS=9V
BIAS=8V
BIAS=7V
DETECTOR OUTPUT (50 mV/IN)
TIME (0.5 SEC/IN)

Figure 102

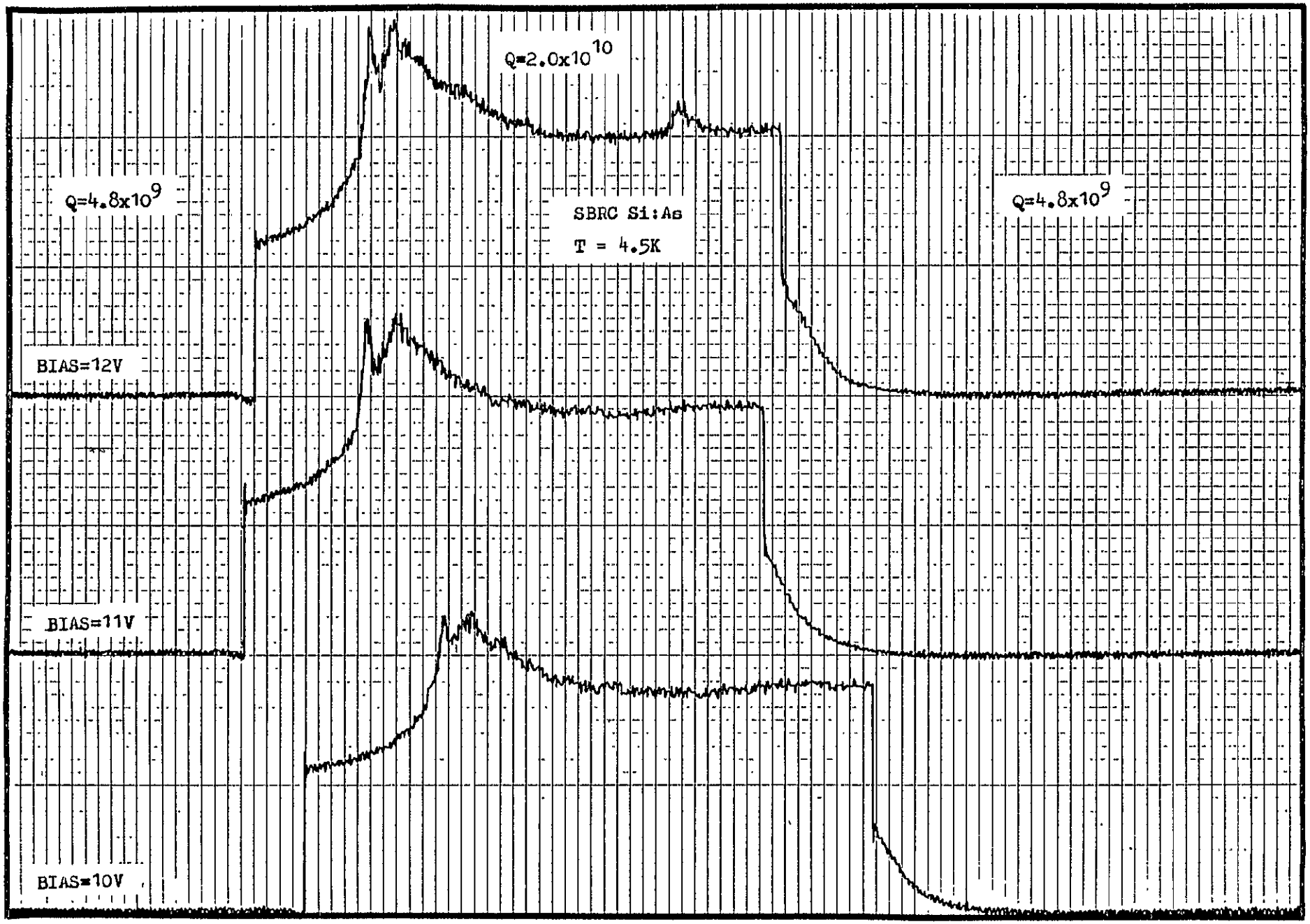

Q=2.0x10^10
Q=4.8x10^9
SBRC Si:As
T = 4.5K
Q=4.8x10^9
BIAS=12V
BIAS=11V
BIAS=10V
DETECTOR OUTPUT (50 mV/IN)
TIME (0.5 SEC/IN)
5 Sec.

Figure 103

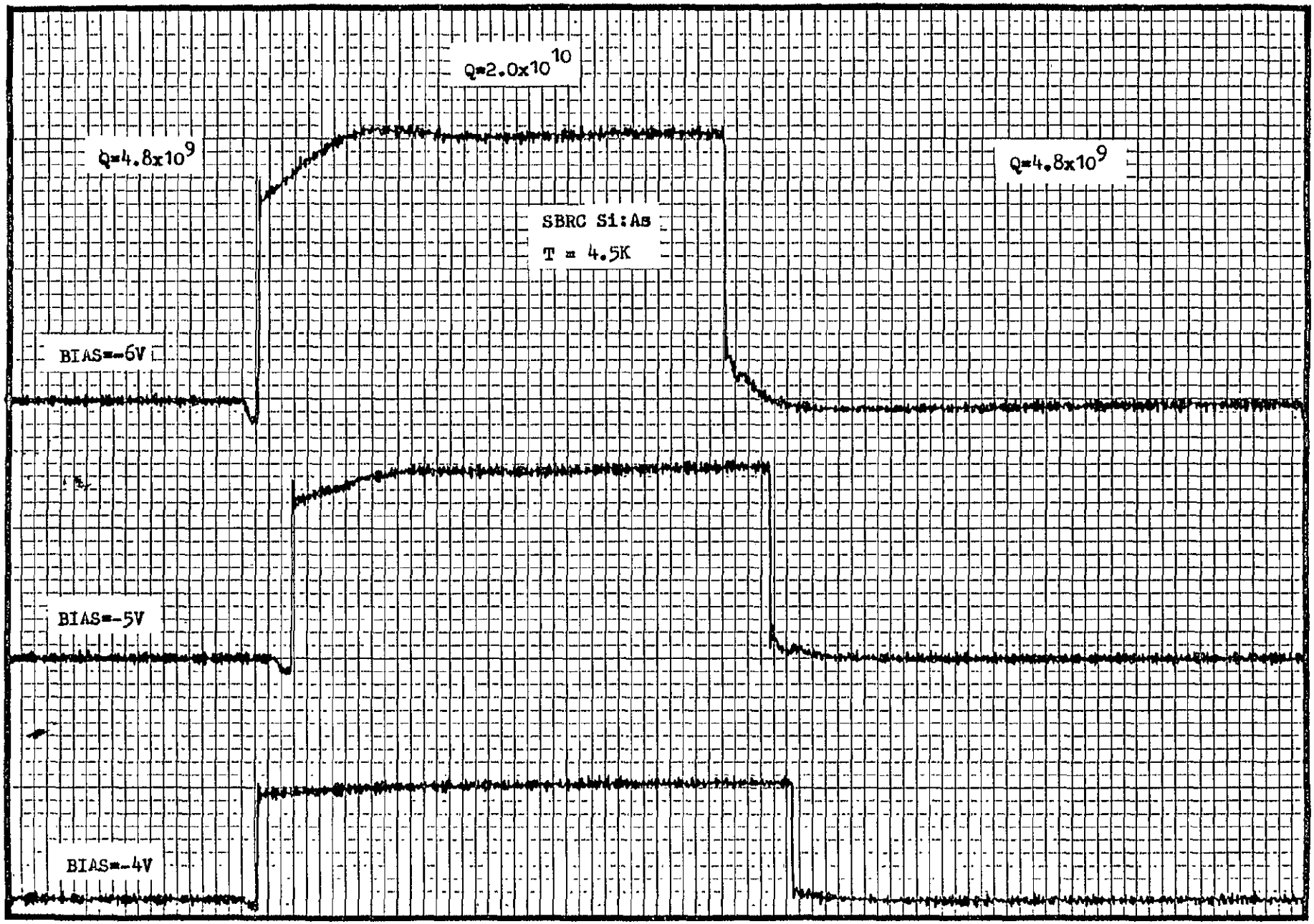

Q=2.0x10^10
Q=4.8x10^9
Q=4.8x10^9
SBRC Si:As
T = 4.5K
BIAS=-6V
BIAS=-5V
BIAS=-4V
DETECTOR OUTPUT(20 mV/IN)
TIME (0.5 SEC/IN)

Figure 104

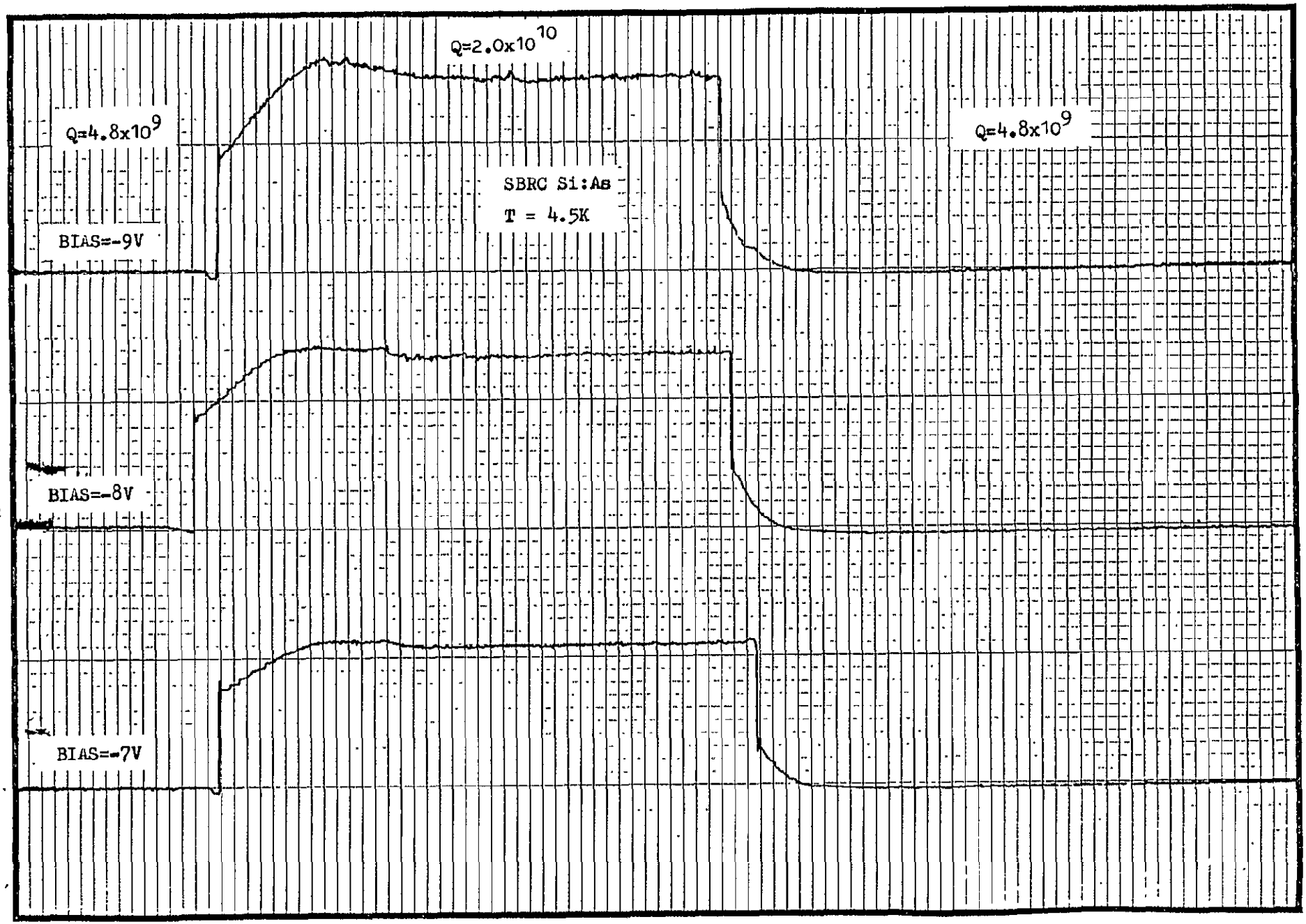

Q=2.0x10^10
Q=4.8x10^9
Q=4.8x10^9
SBRC Si:As
T = 4.5K
BIAS=-9V
BIAS=-8V
BIAS=-7V
DETECTOR OUTPUT (50 mV/IN)
TIME (0.5 SEC/IN)

Figure 105

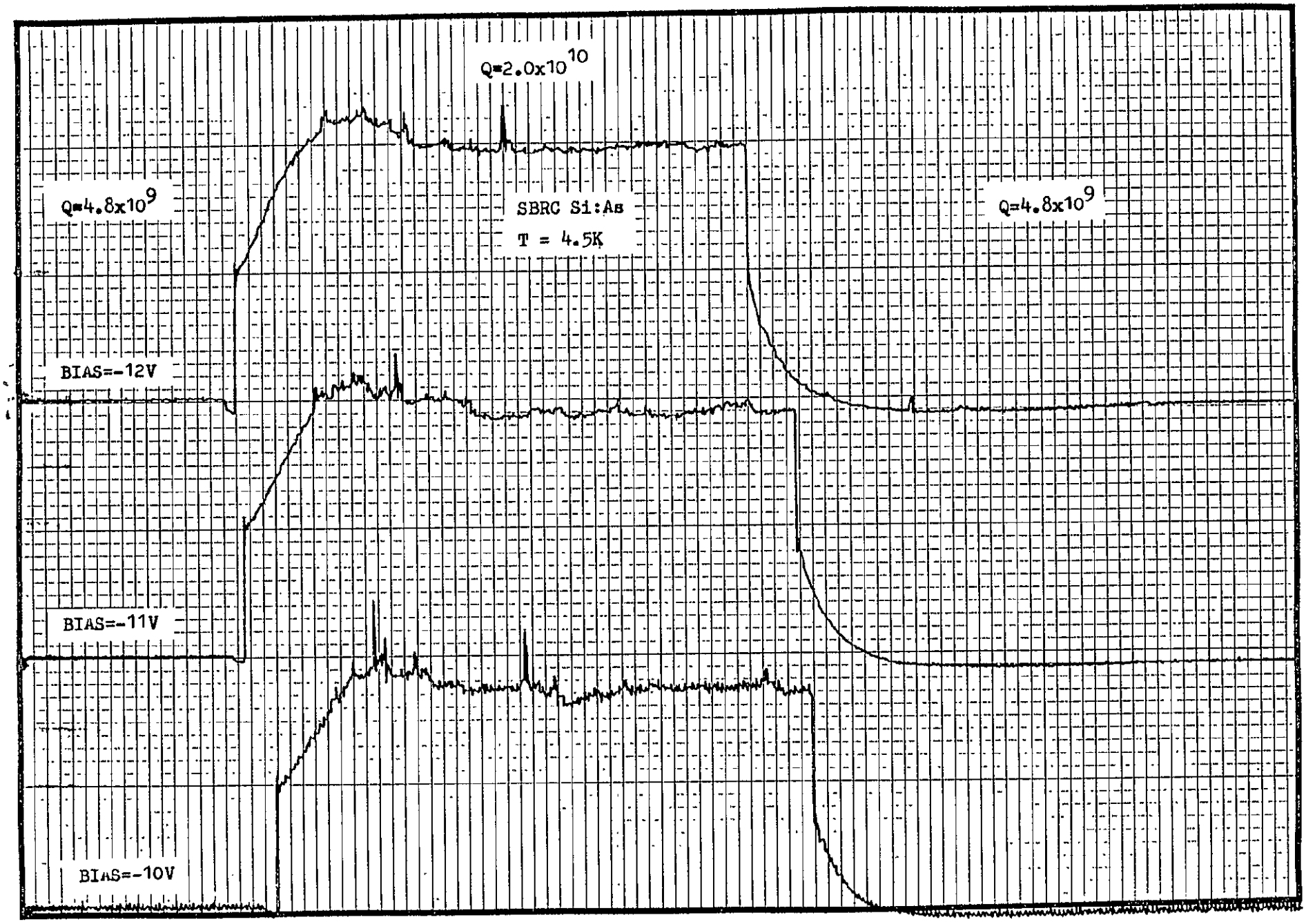

Q=2.0x10^10
Q=4.8x10^9
SBRC Si:As
T = 4.5K
Q=4.8x10^9
BIAS=-12V
BIAS=-11V
BIAS=-10V
DETECTOR OUTPUT (50 mV/IN)
TIME (0.5 SEC/IN)

Figure 106

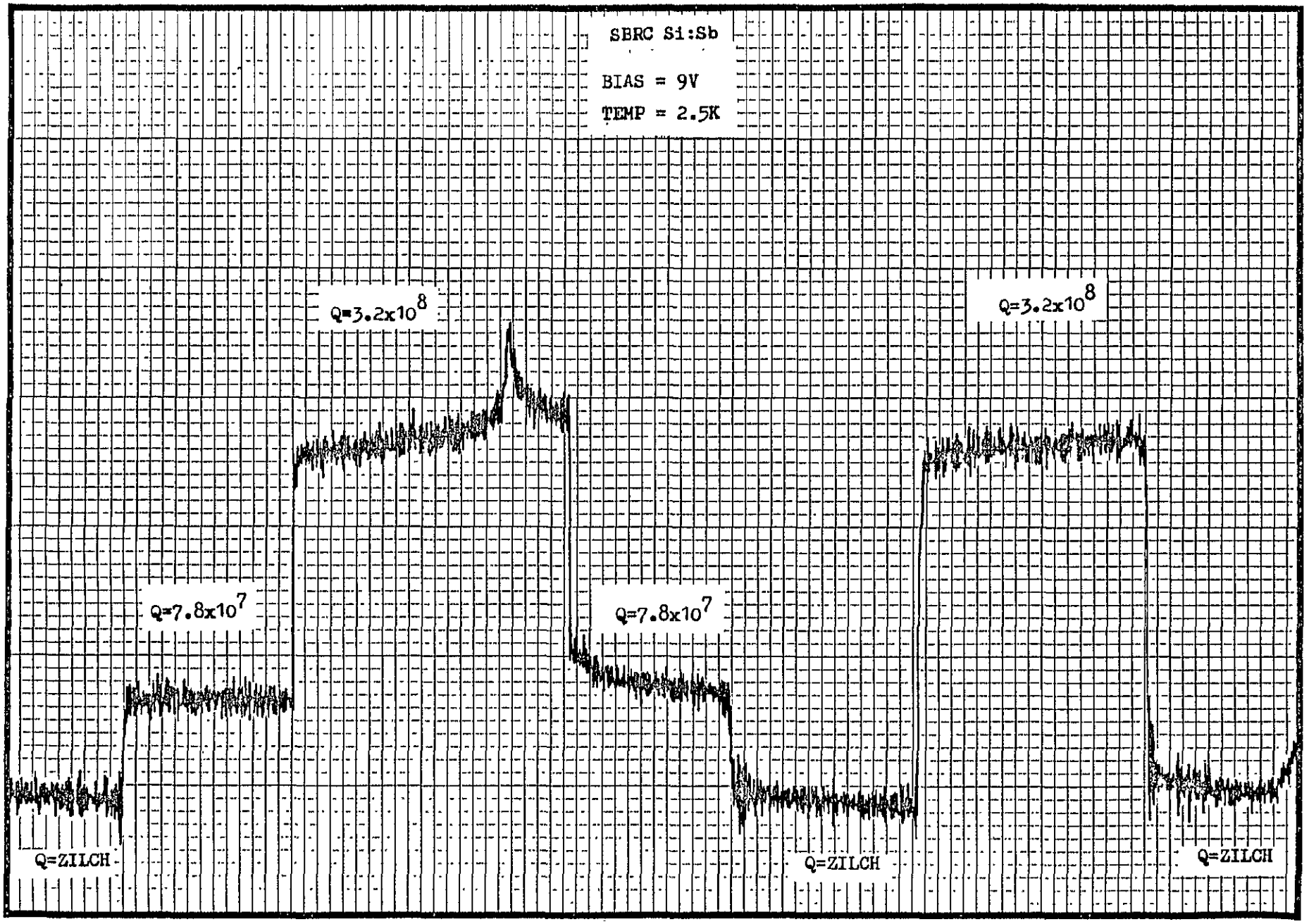

SBRC Si:Sb
BIAS = 9V
TEMP = 2.5K
Q=3.2x10^8
Q=3.2x10^8
Q=7.8x10^7
Q=7.8x10^7
Q=ZILCH
Q=ZILCH
Q=ZILCH
OUTPUT (500 uV/IN)
TIME (10 SEC/IN)

Figure 107

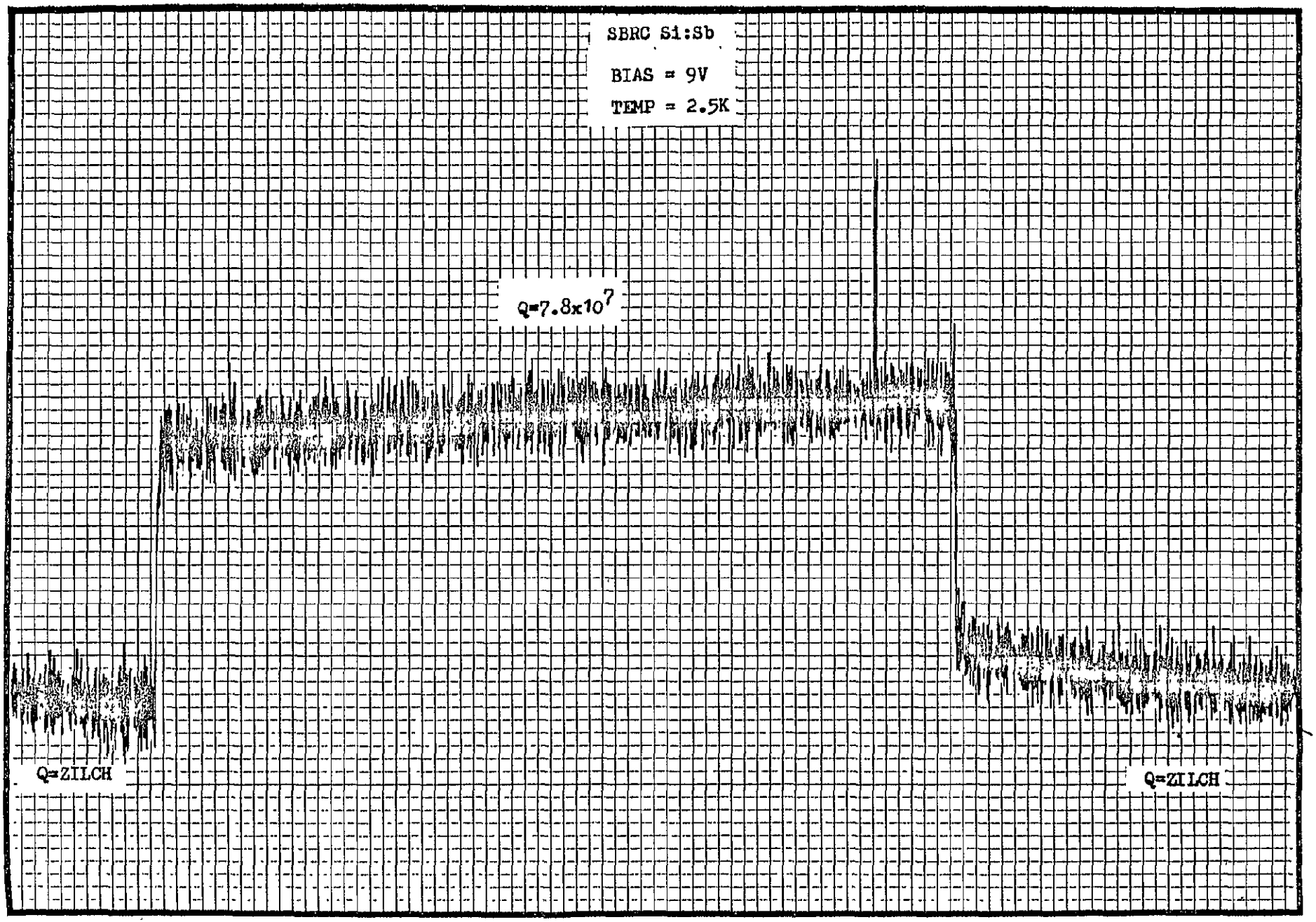

SBRC Si:Sb
BIAS = 9V
TEMP = 2.5K
Q=7.8x10^7
Q=ZILCH
Q=ZILCH
OUTPUT (200 μV/IN)
TIME (20 SEC/IN)

Figure 108

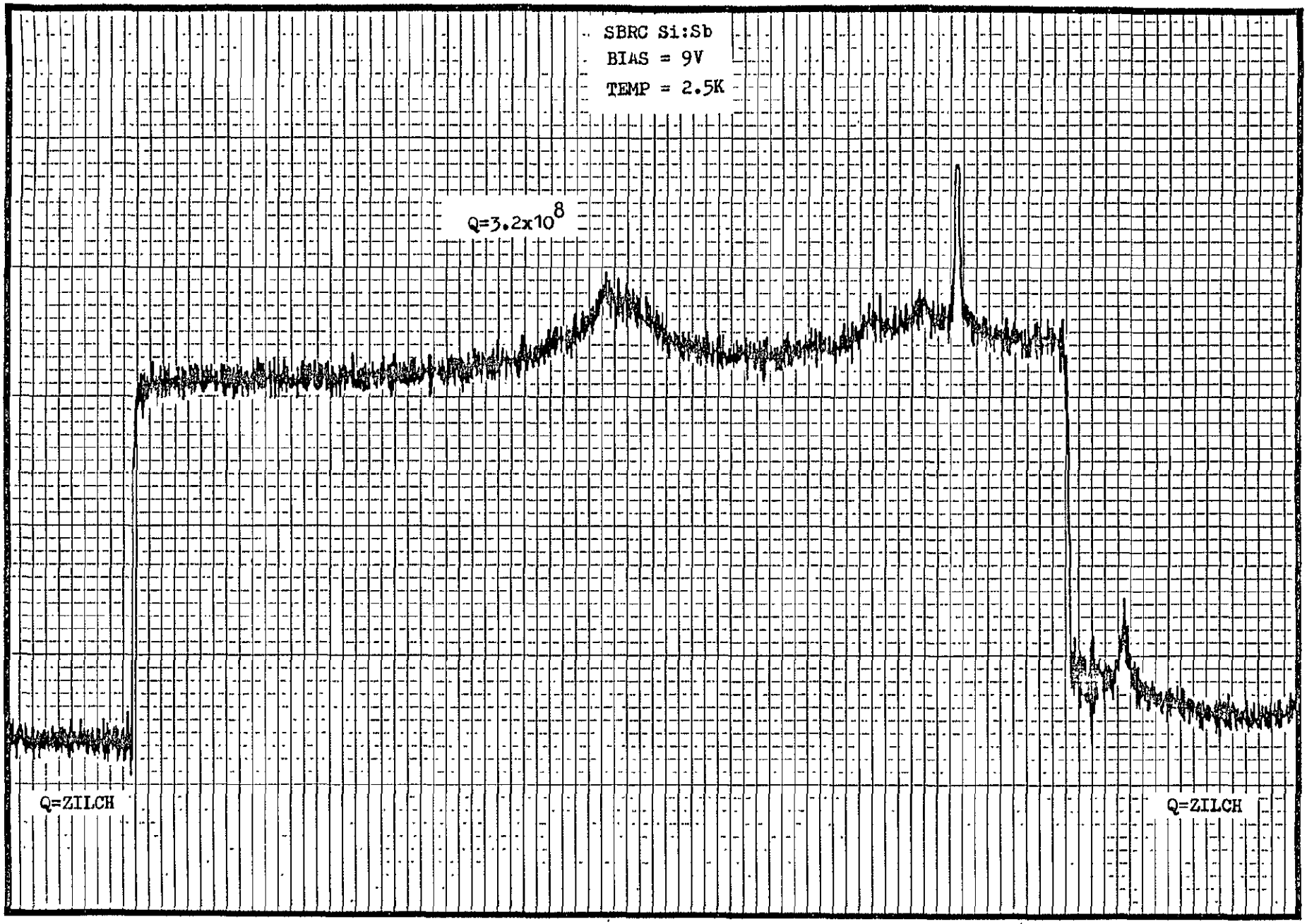

SBRC Si:Sb
BIAS = 9V
TEMP = 2.5K
Q=3.2x10^8
Q=ZILCH
Q=ZILCH
OUTPUT (500 μV/IN)
TIME (10 SEC/IN)

Figure 109

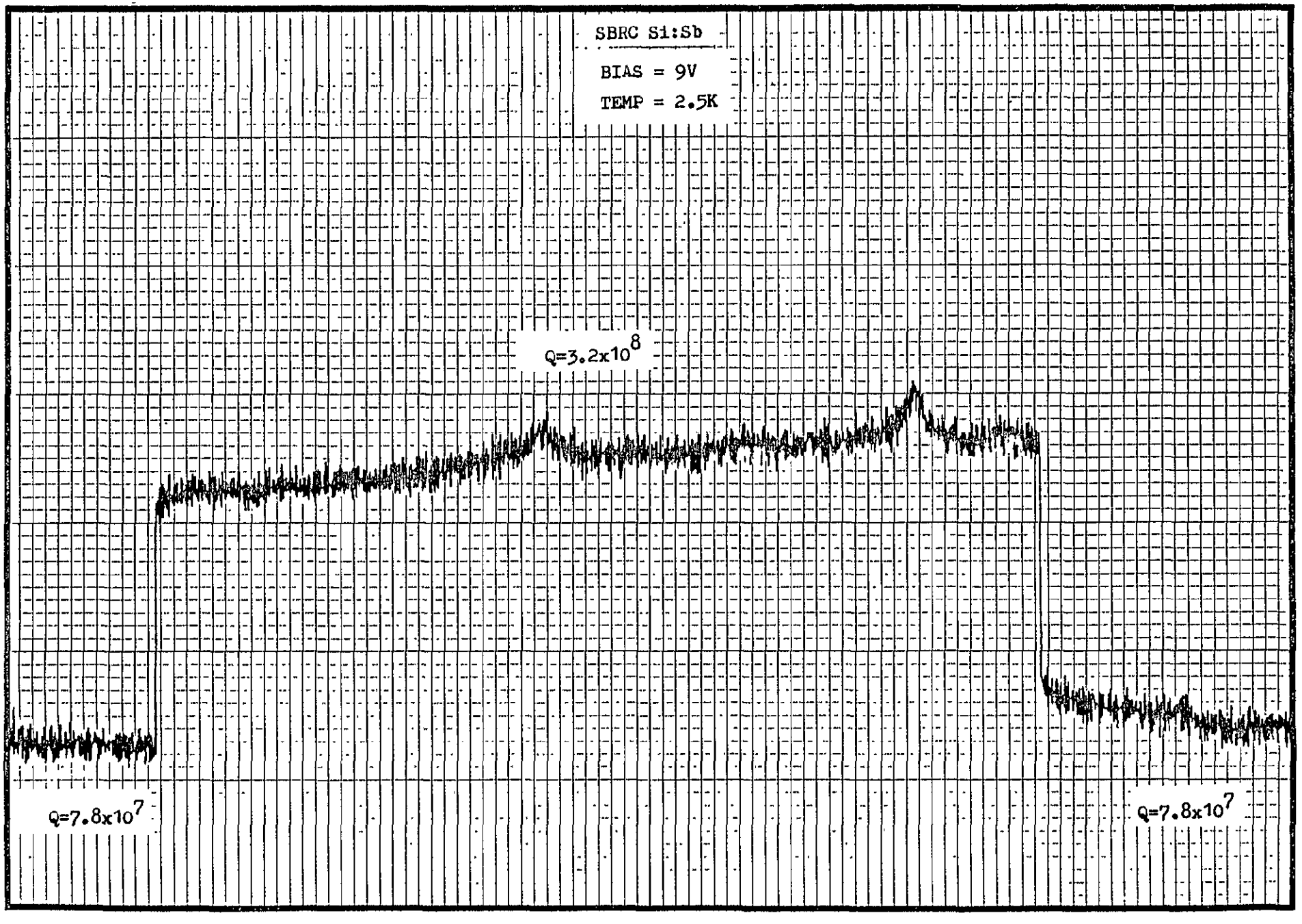

SBRC Si:Sb
BIAS = 9V
TEMP = 2.5K
Q=3.2x10^8
Q=7.8x10^7
Q=7.8x10^7
OUTPUT (500 μV/IN)
TIME (10 SEC/IN)

Figure 110

SBRC Si:Sb
BIAS = 9V
TEMP = 2.5K
Q=3.2x10^8
Q=7.8x10^7
OUTPUT (500 MV/IN)
TIME (10 SEC/IN)

Figure 111

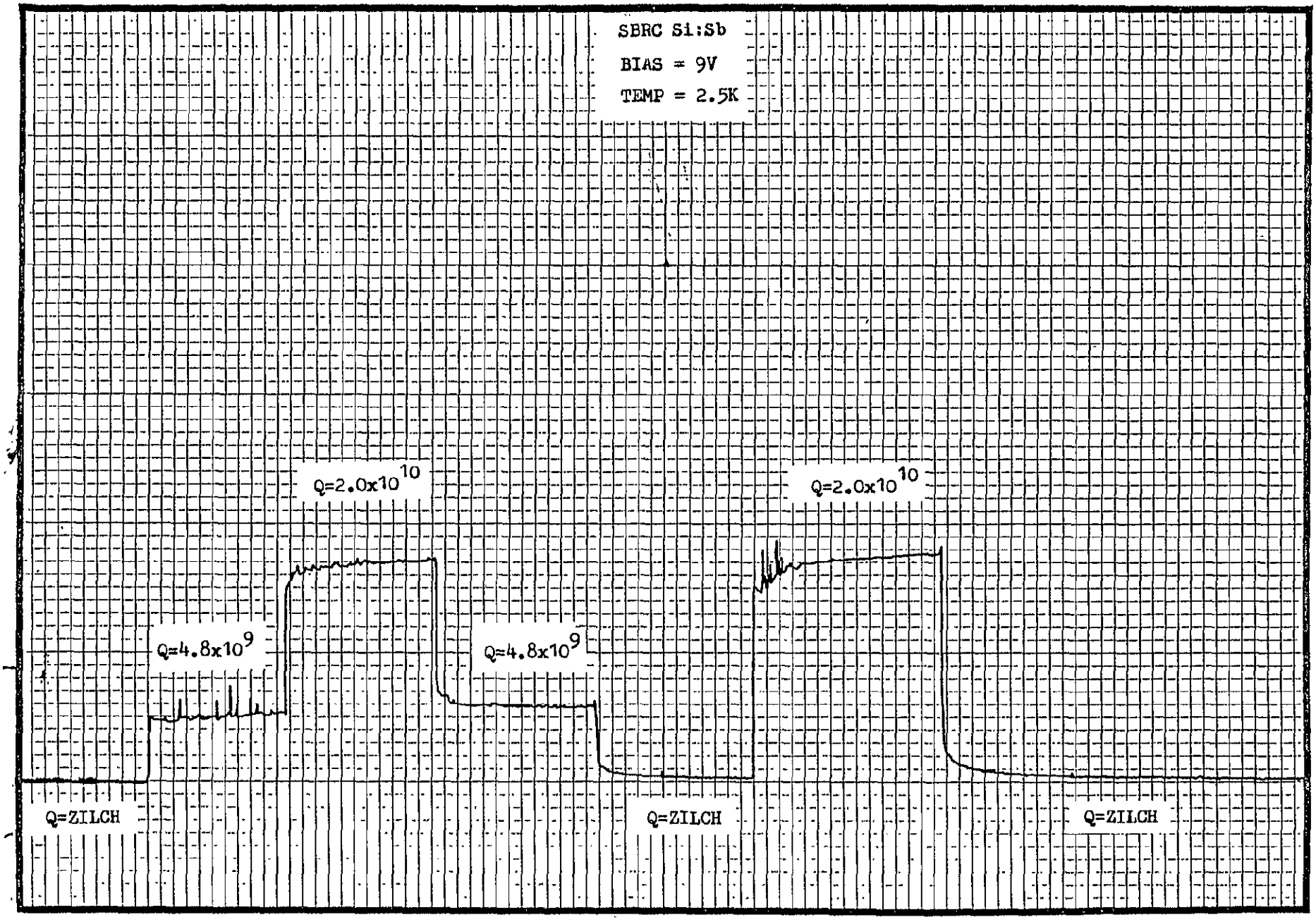

SBRC Si:Sb
BIAS = 9V
TEMP = 2.5K
Q=2.0x10^10
Q=2.0x10^10
Q=4.8x10^9
Q=4.8x10^9
Q=ZILCH
Q=ZILCH
Q=ZILCH
OUTPUT (50 mV/IN)
TIME (10 SEC/IN)

Figure 112

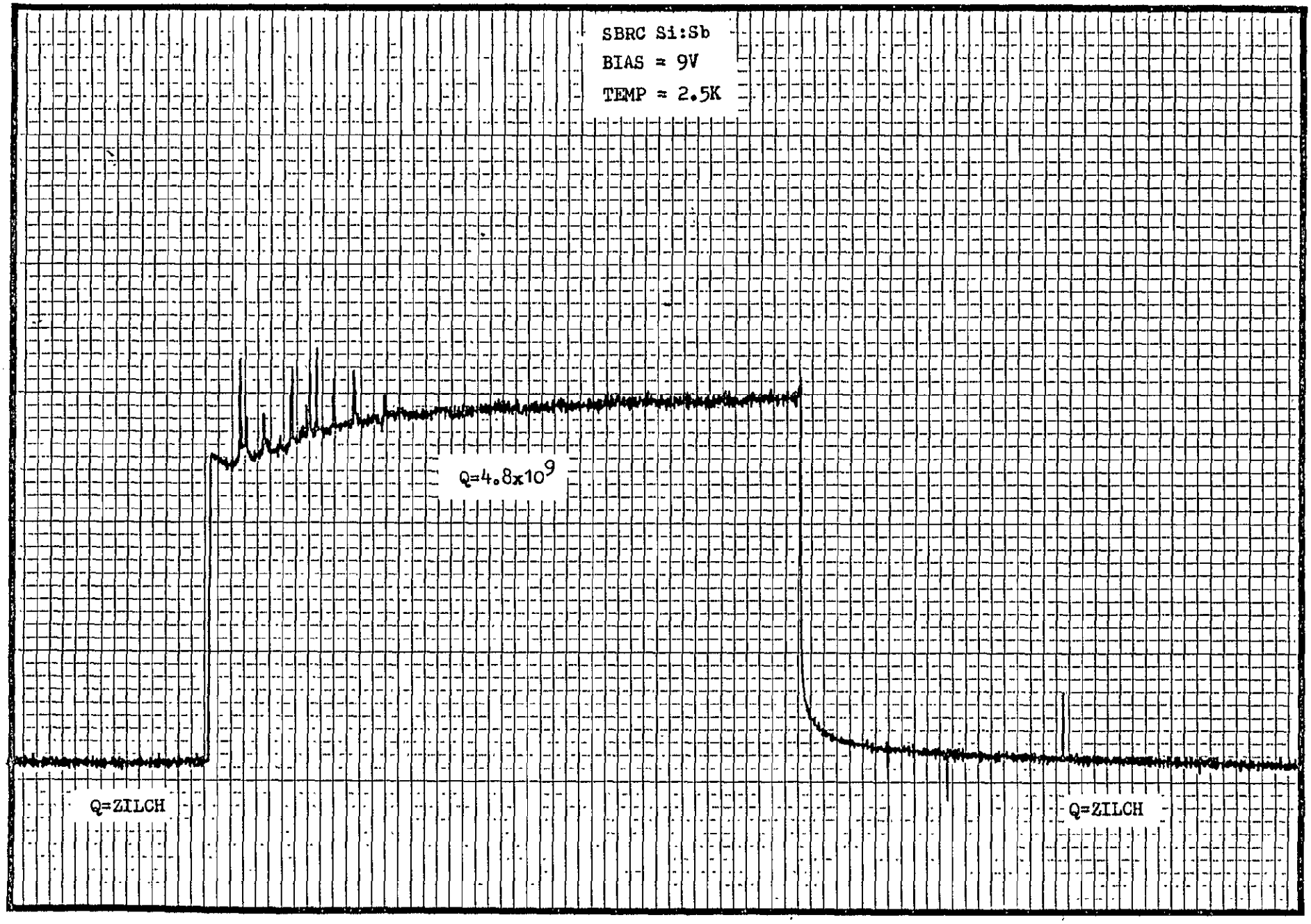

SBRC Si:Sb
BIAS = 9V
TEMP = 2.5K
Q=4.8x10^9
Q=ZILCH
Q=ZILCH
OUTPUT (10 mV/IN)
TIME (10 SEC/IN)

Figure 113

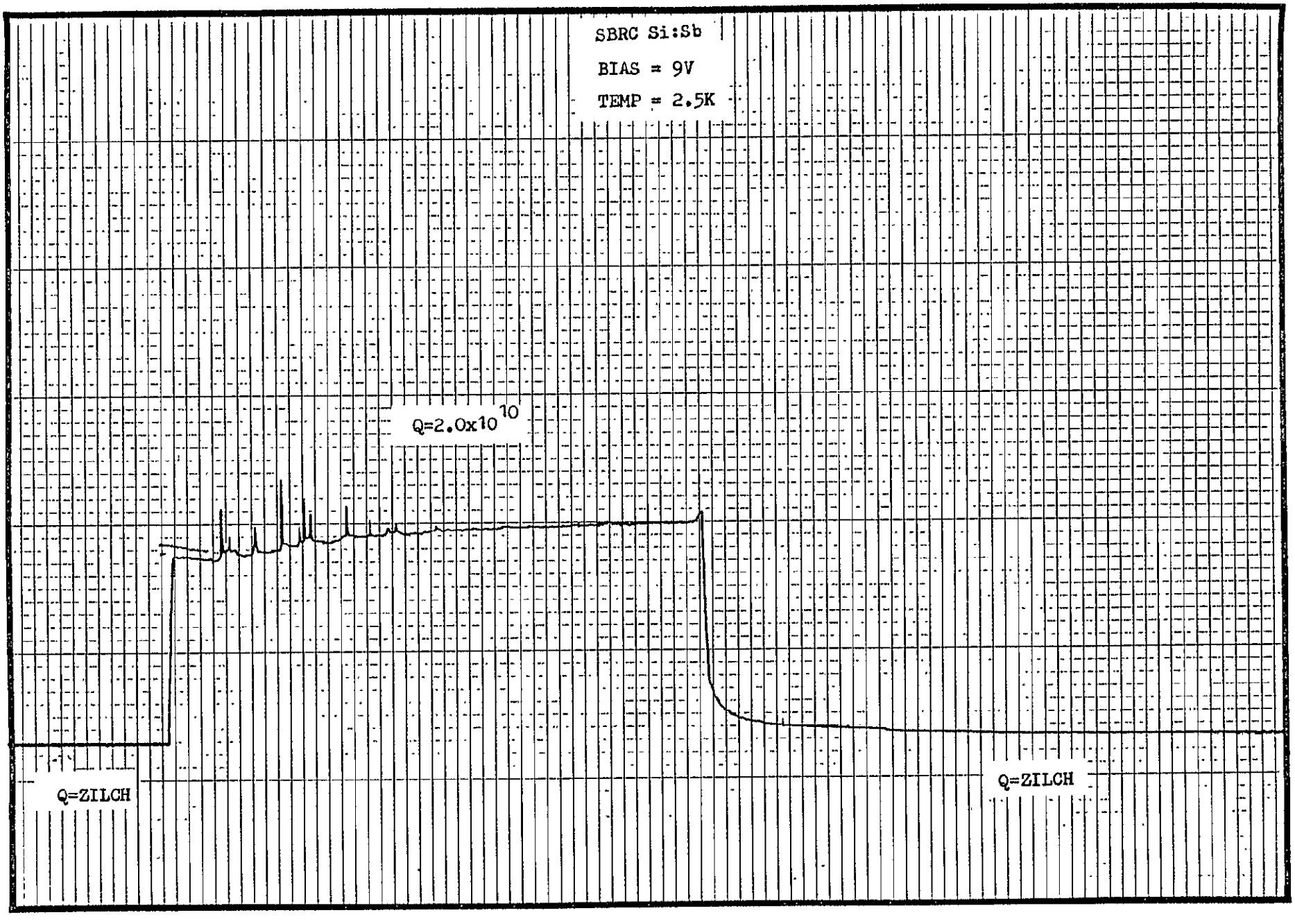

SBRC Si:Sb
BIAS = 9V
TEMP = 2.5K
Q=2.0x10^10
Q=ZILCH
Q=ZILCH
OUTPUT (50 mV/IN)
TIME (2 SEC/IN)

Figure 114

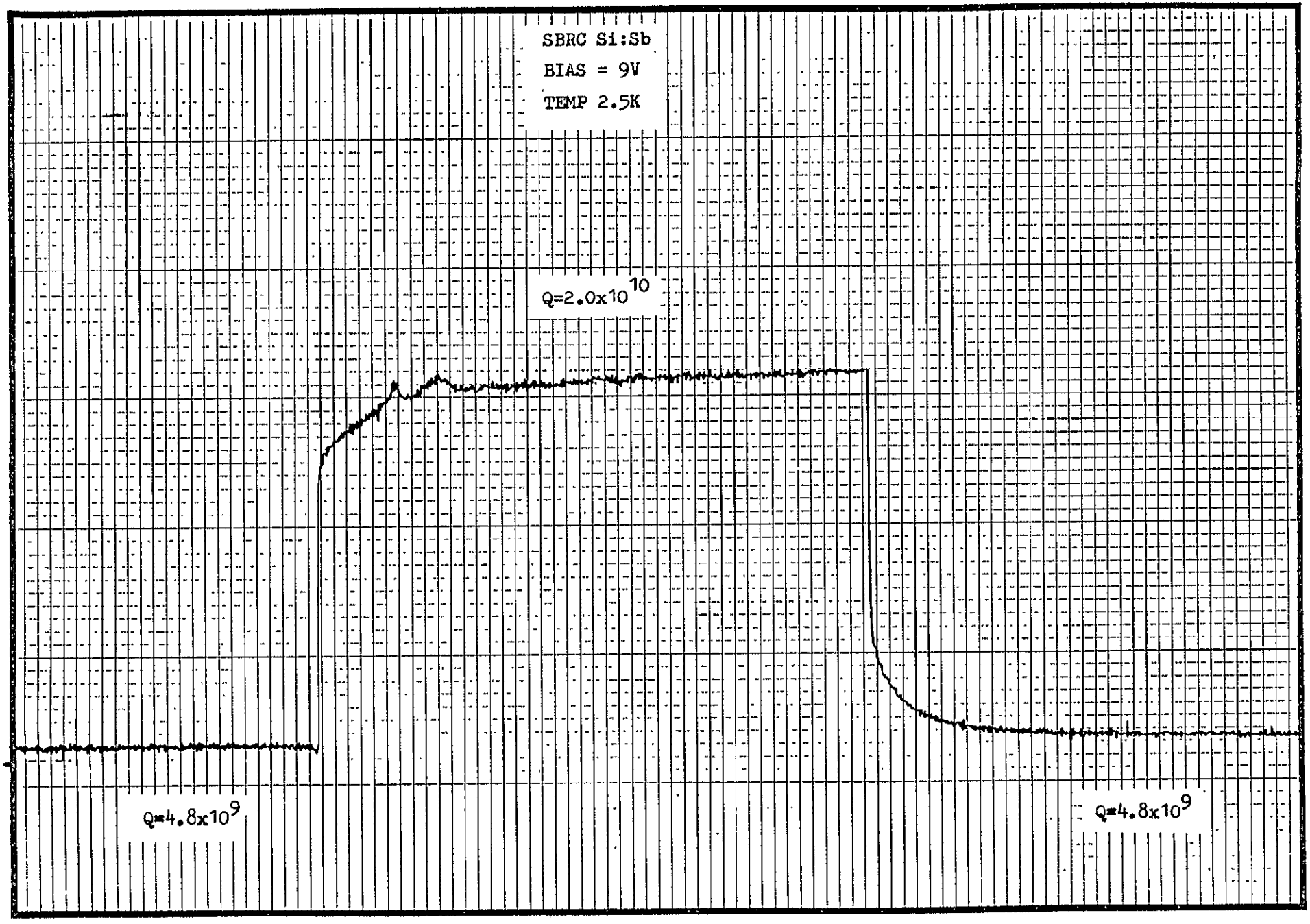

SBRC Si:Sb
BIAS = 9V
TEMP 2.5K
Q=2.0x10^10
Q=4.8x10^9
Q=4.8x10^9
OUTPUT (20 mV/IN)
TIME (1 SEC/IN)

Figure 115

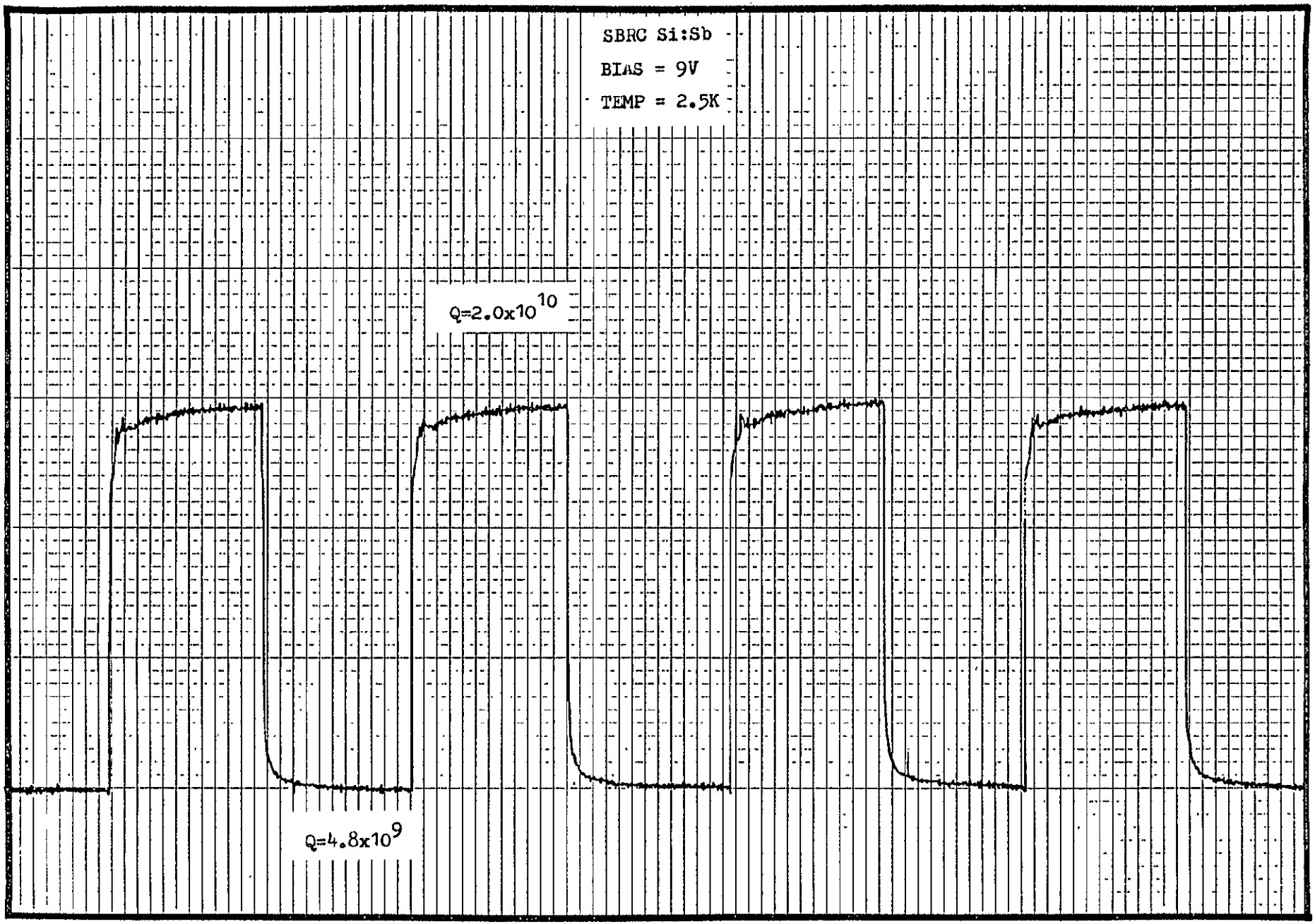

SBRC Si:Sb
BIAS = 9V
TEMP = 2.5K
Q=2.0x10^10
Q=4.8x10^9
OUTPUT (20 mV/IN)
TIME (10 SEC/IN)

Figure 116

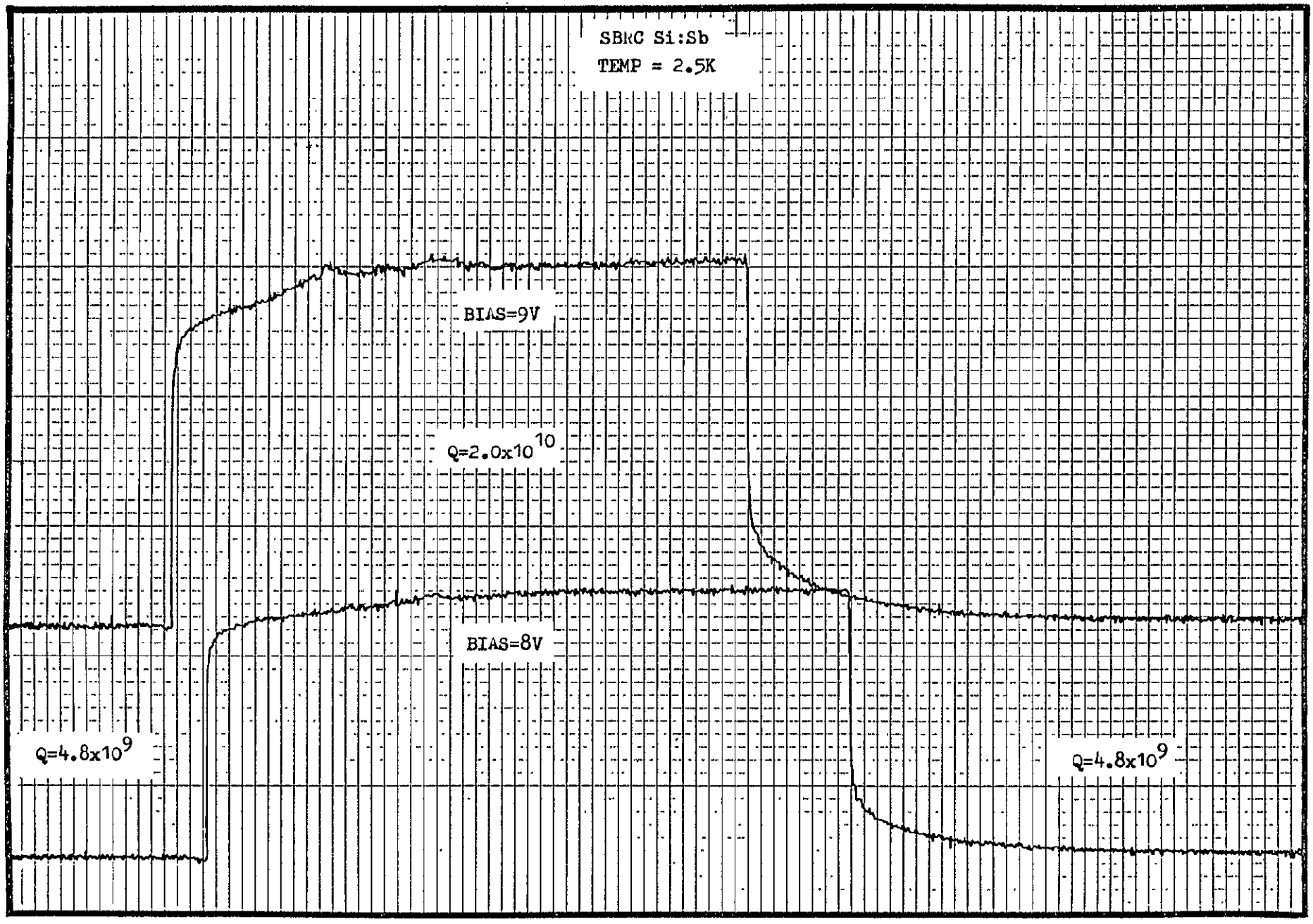

SBRC Si:Sb
TEMP = 2.5K
BIAS=9V
Q=2.0x10^10
BIAS=8V
Q=4.8x10^9
Q=4.8x10^9
OUTPUT (20 mV/IN)
TIME (0.5 SEC/IN)

Figure 117

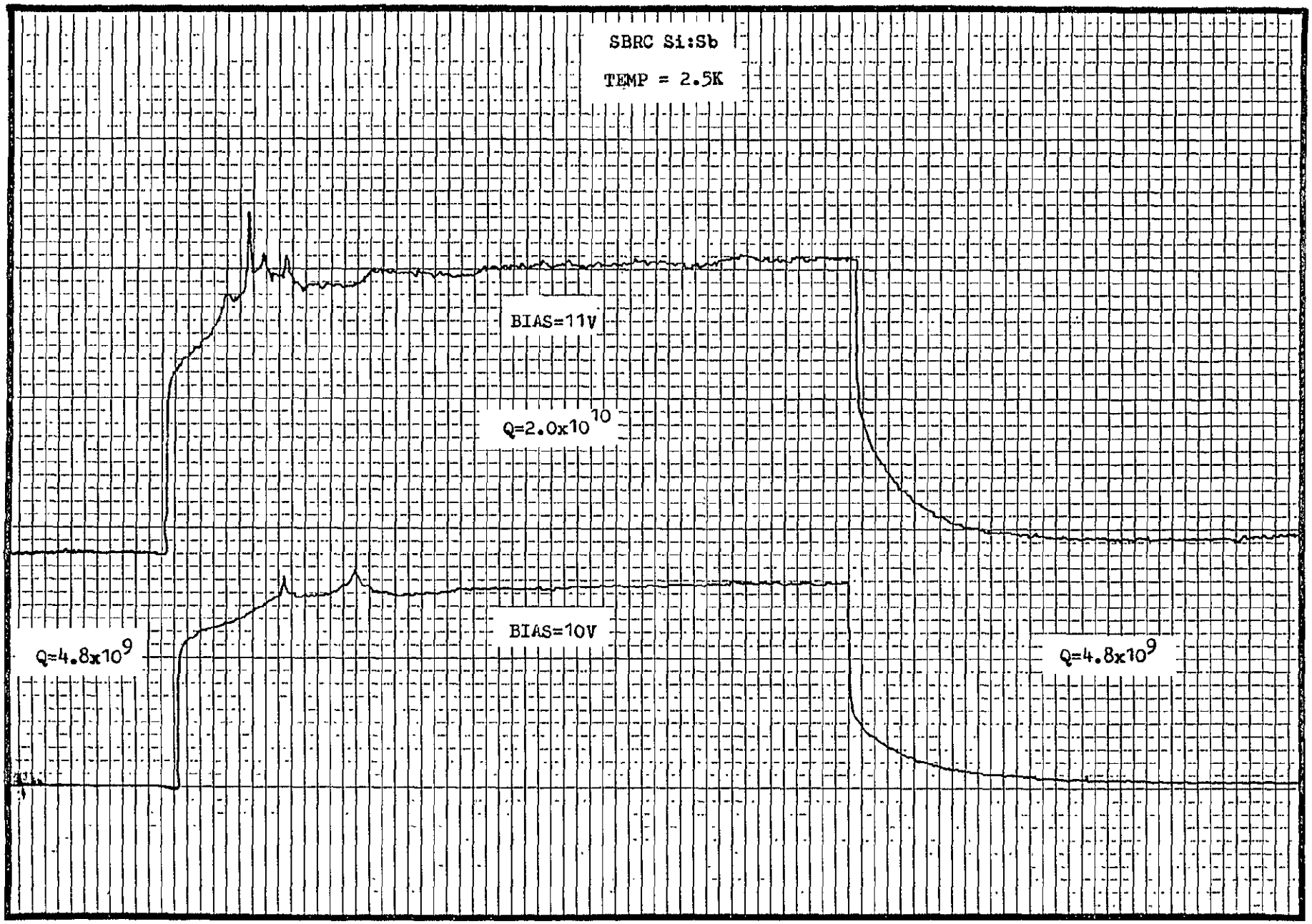

SBRC Si:Sb
TEMP = 2.5K
BIAS=11V
Q=2.0x10^10
BIAS=10V
Q=4.8x10^9
Q=4.8x10^9
OUTPUT (50 mV/IN)
TIME (0.5 SEC/IN)

Figure 118

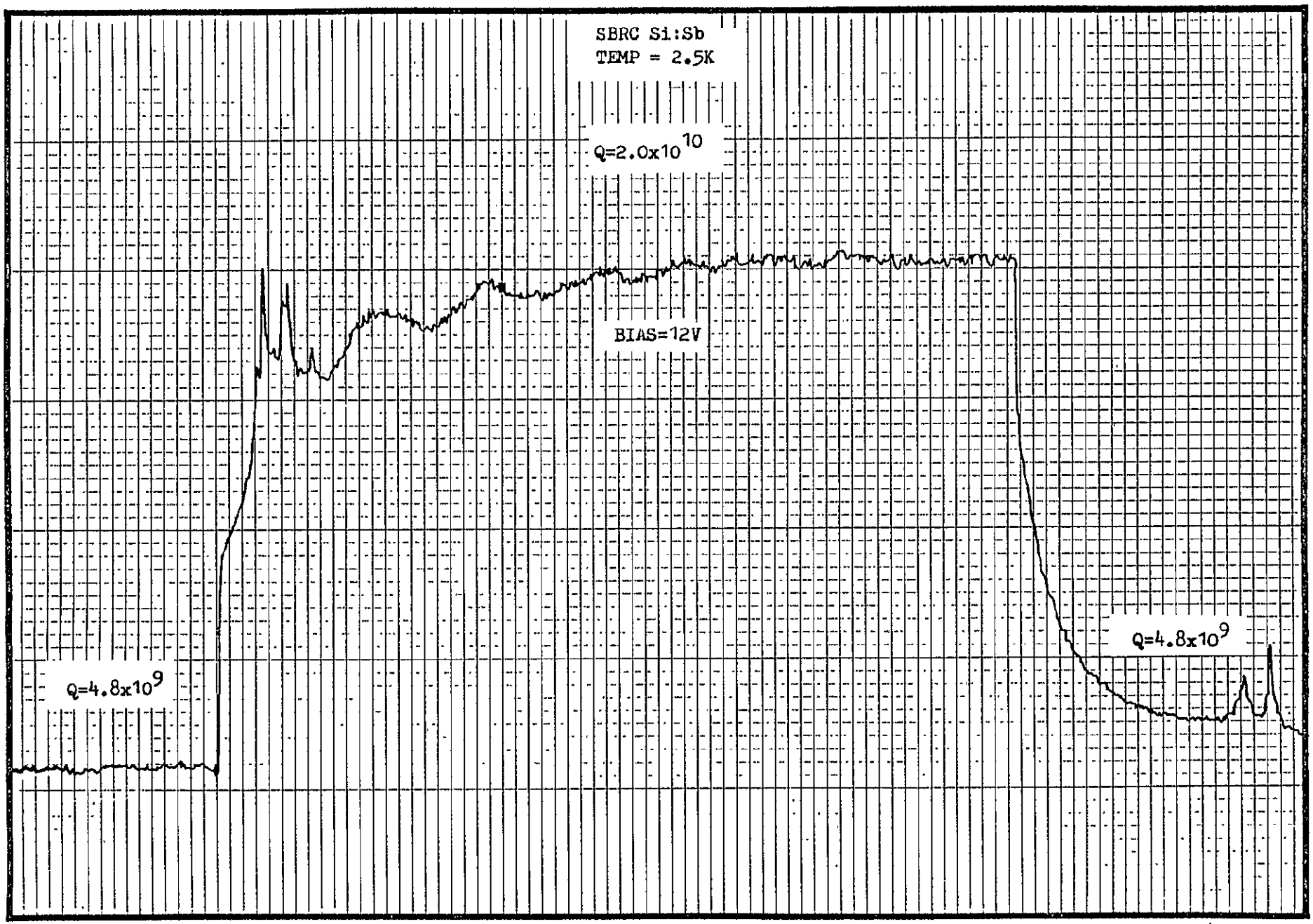

SBRC Si:Sb
TEMP = 2.5K
Q=2.0x10^10
BIAS=12V
Q=4.8x10^9
Q=4.8x10^9
OUTPUT (50 mV/IN)
TIME (0.5 SEC/IN)

Figure 119

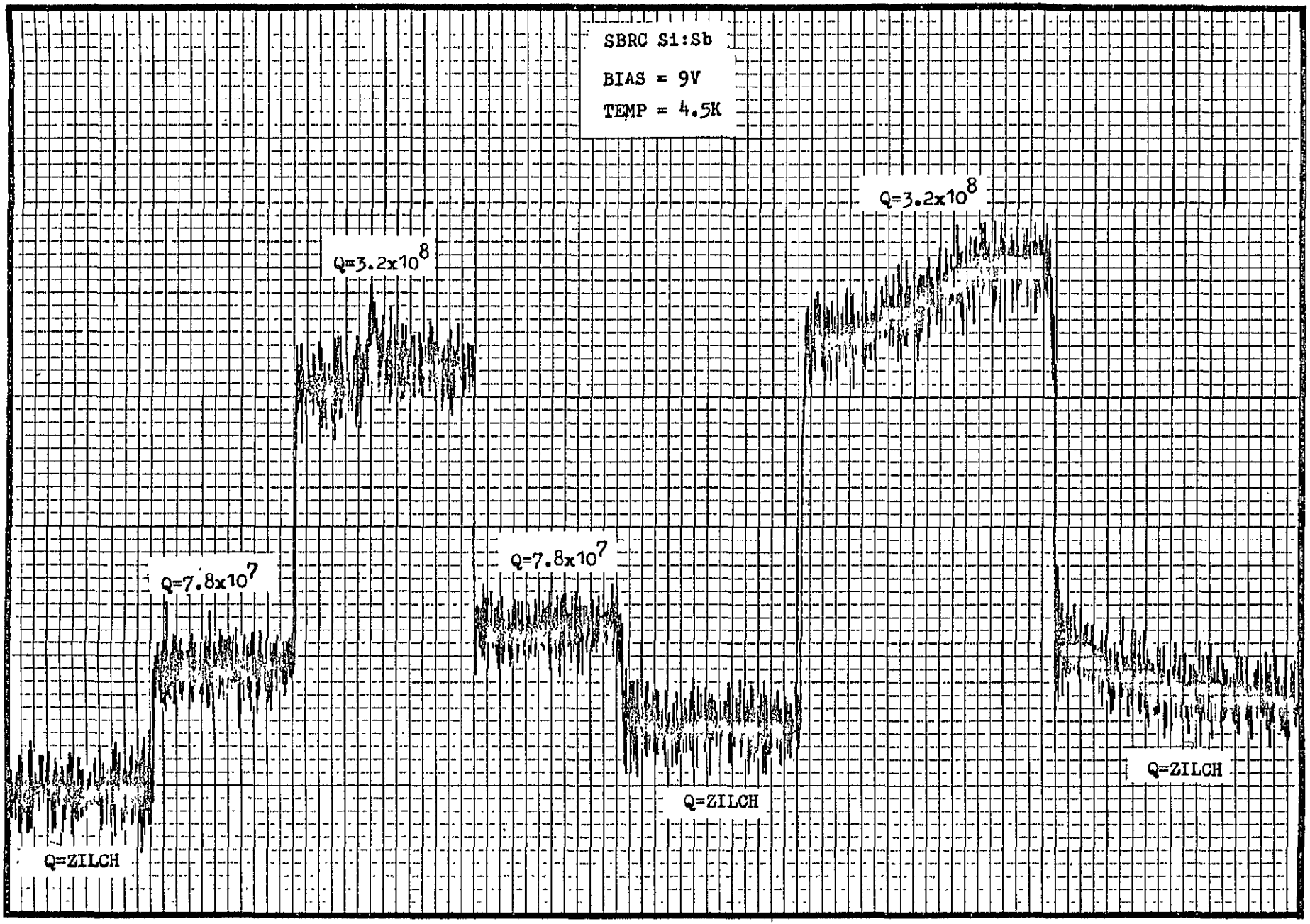

SBRC Si:Sb
BIAS = 9V
TEMP = 4.5K
Q=3.2x10^8
Q=3.2x10^8
Q=7.8x10^7
Q=7.8x10^7
Q=ZILCH
Q=ZILCH
Q=ZILCH
OUTPUT(200μV/IN)
TIME (10 SEC/IN)

Figure 120

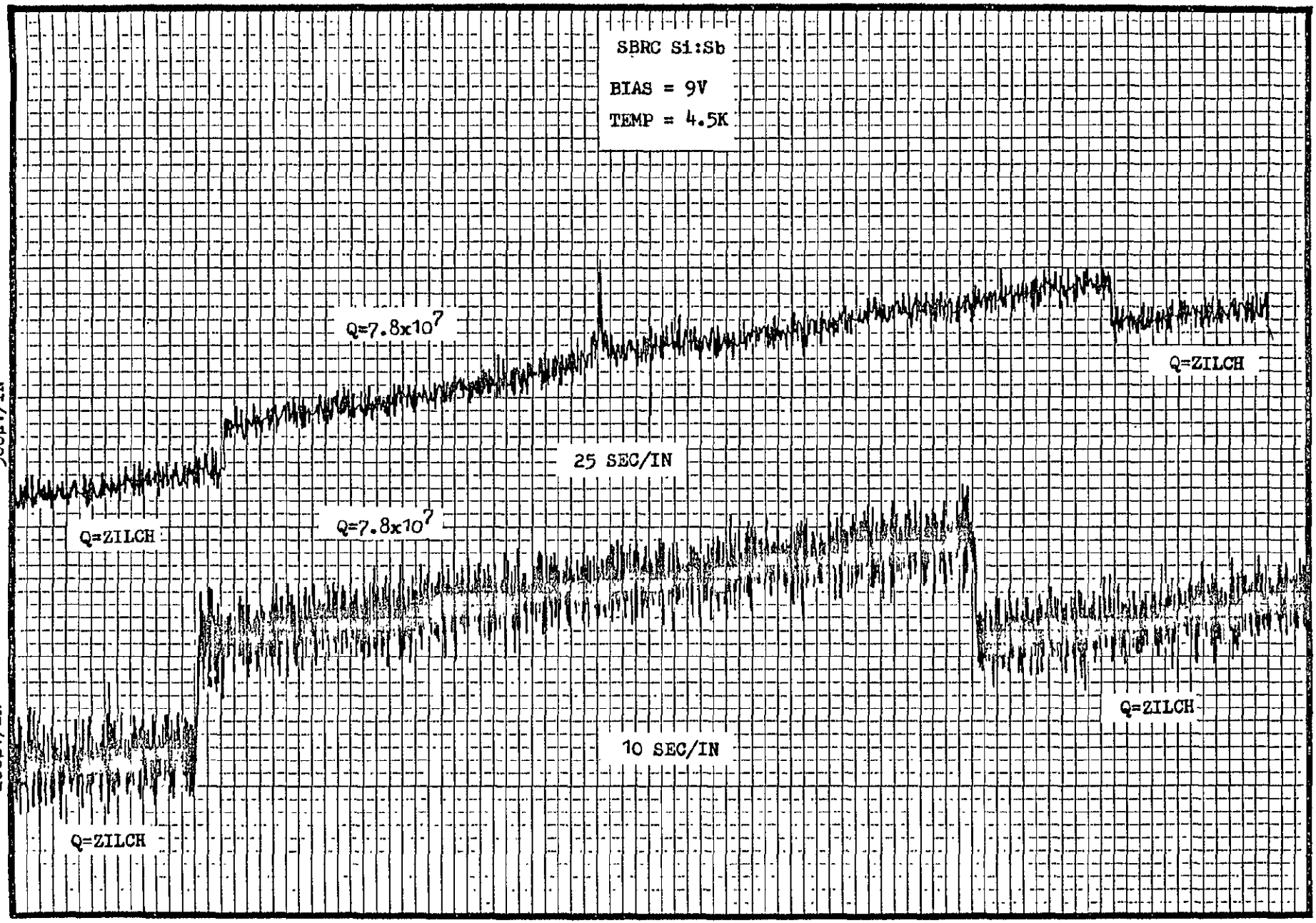

SBRC Si:Sb
BIAS = 9V
TEMP = 4.5K
Q=7.8x10^7
Q=ZILCH
25 SEC/IN
Q=7.8x10^7
Q=ZILCH
Q=ZILCH
10 SEC/IN
Q=ZILCH
500μV/IN
200μV/IN
OUTPUT VOLTAGE
TIME

Figure 121

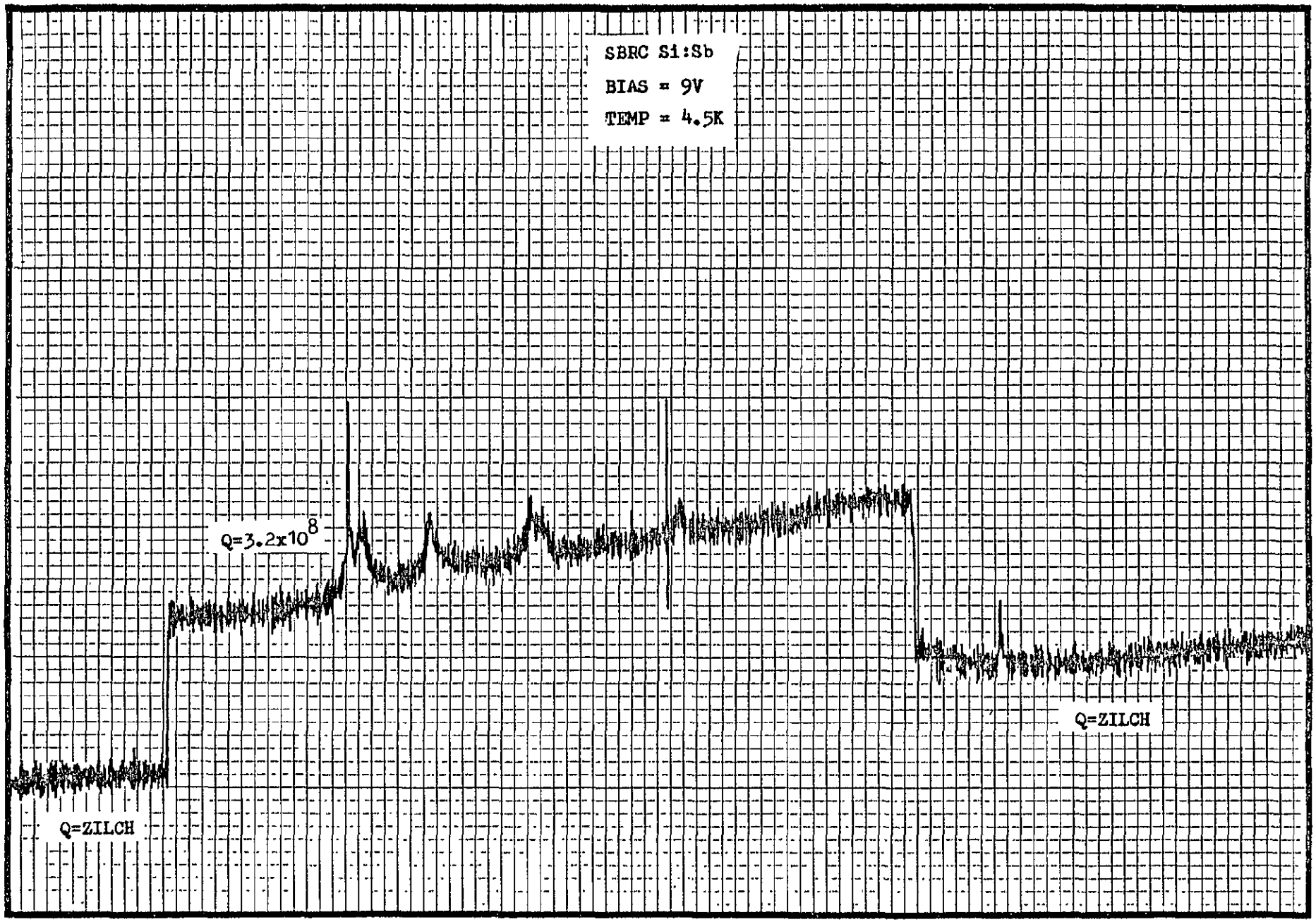

SBRC Si:Sb
BIAS = 9V
TEMP = 4.5K
Q=3.2x10^8
Q=ZILCH
Q=ZILCH
OUTPUT (500μV/IN)
TIME (20 SEC/IN)

Figure 122

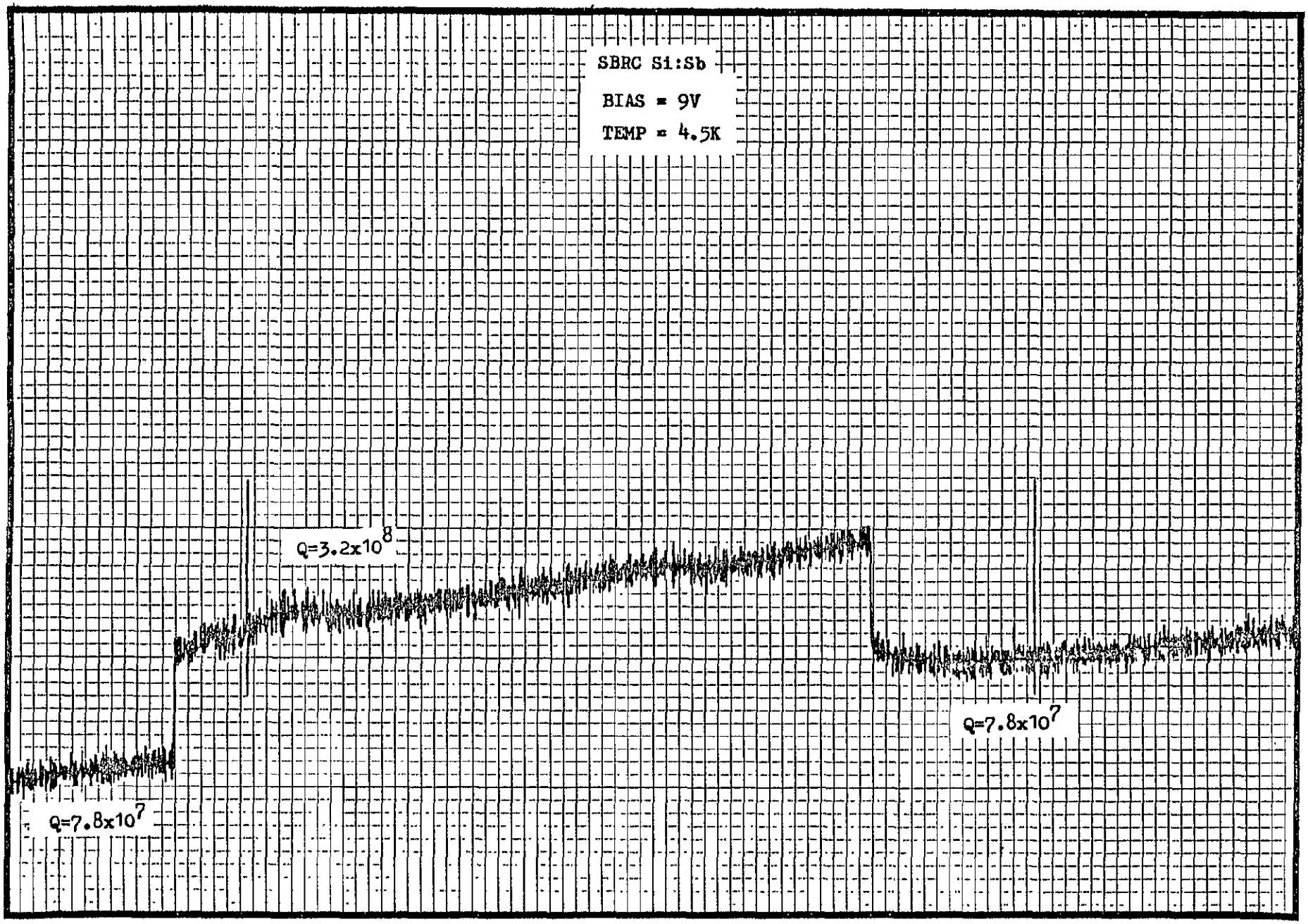

SBRC Si:Sb
BIAS = 9V
TEMP = 4.5K
Q=3.2x10^8
Q=7.8x10^7
Q=7.8x10^7
OUTPUT (500μV/IN)
TIME (20 SEC/IN)

Figure 123

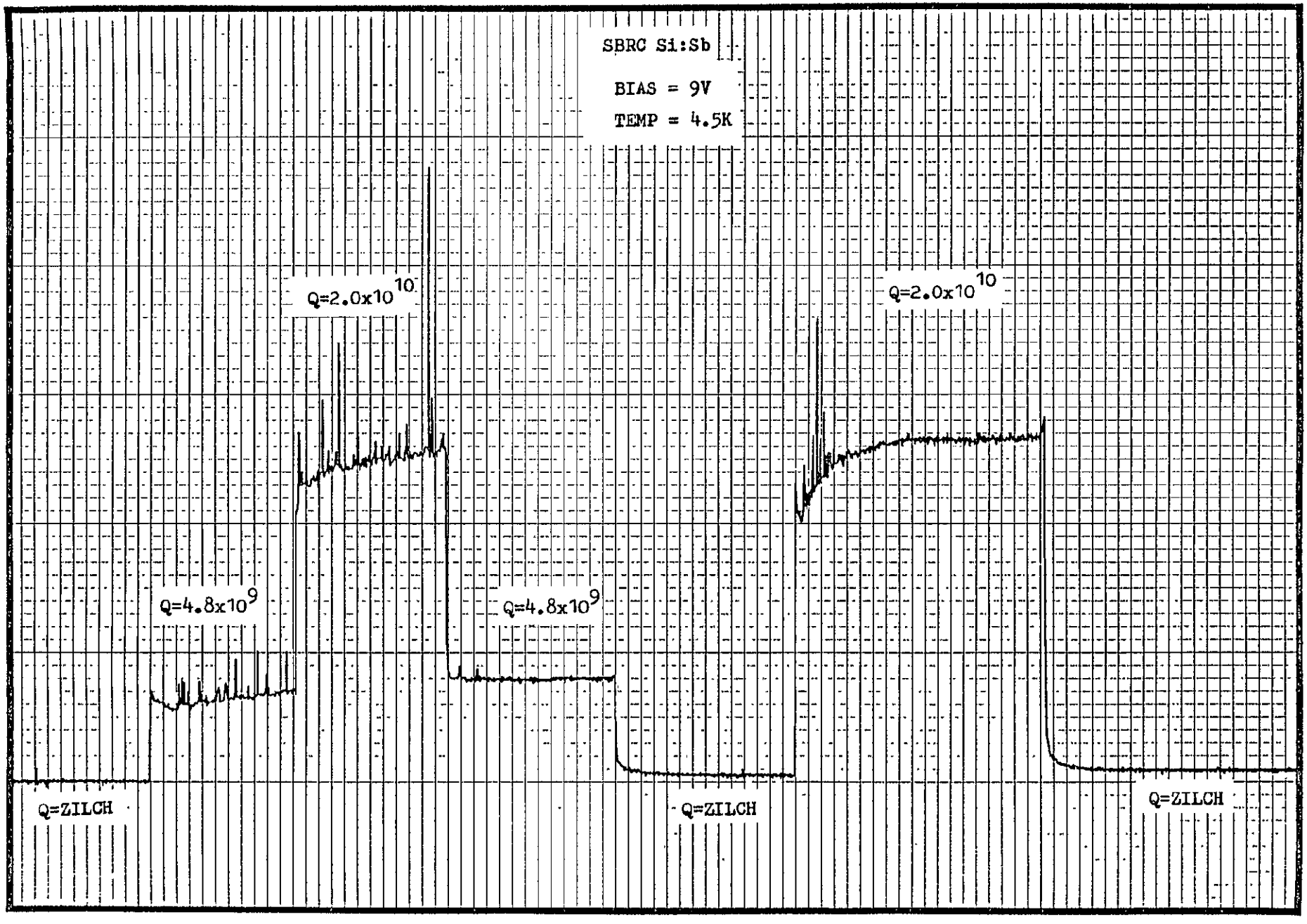

SBRC Si:Sb
BIAS = 9V
TEMP = 4.5K
Q=2.0x10^10
Q=2.0x10^10
Q=4.8x10^9
Q=4.8x10^9
Q=ZILCH
Q=ZILCH
Q=ZILCH
OUTPUT (20 mV/IN)
TIME (10 SEC/IN)

Figure 124

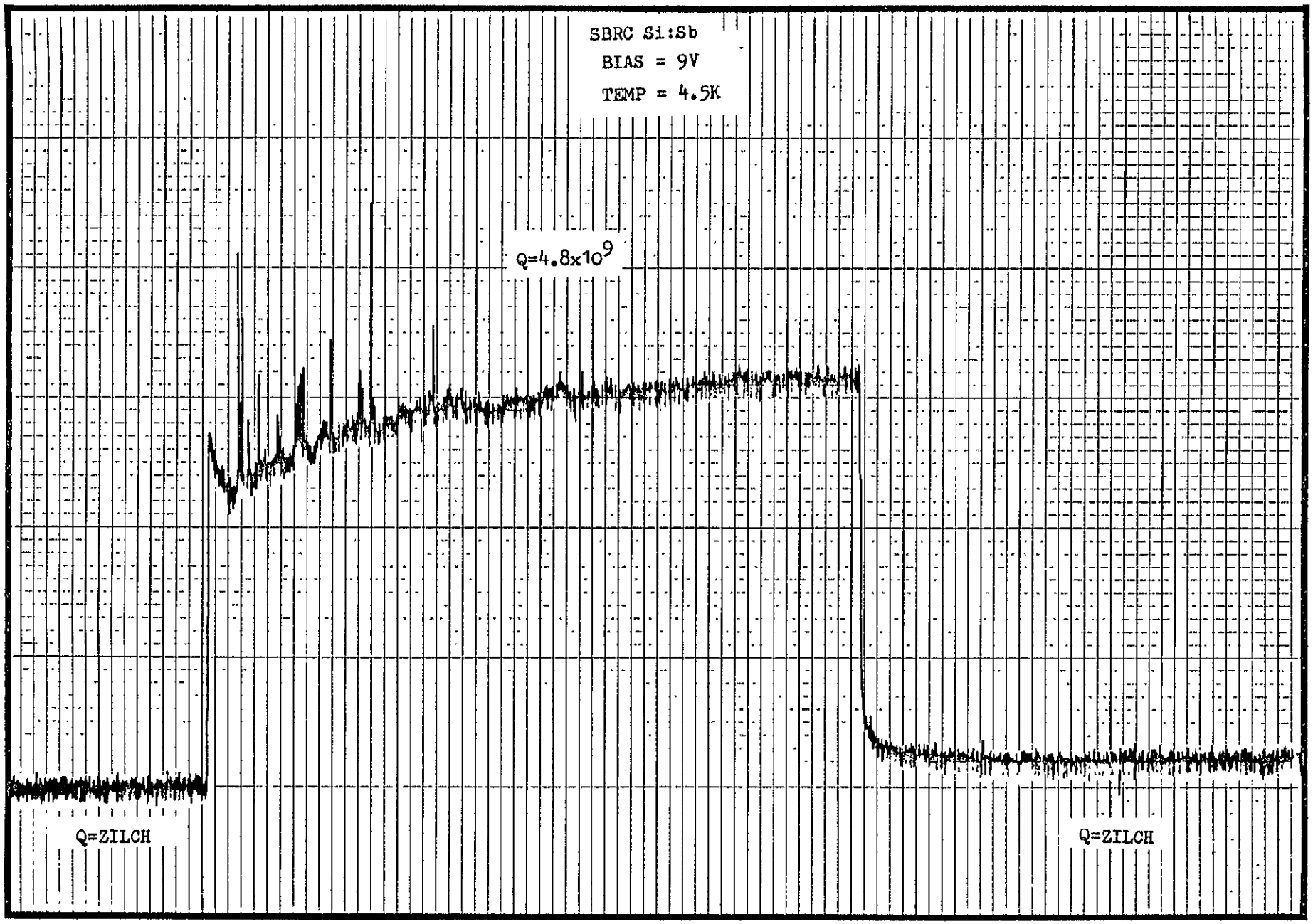

SBRC Si:Sb
BIAS = 9V
TEMP = 4.5K
Q=4.8x10^9
Q=ZILCH
Q=ZILCH
OUTPUT (5 mV/IN)
TIME (10 SEC/IN)

Figure 125

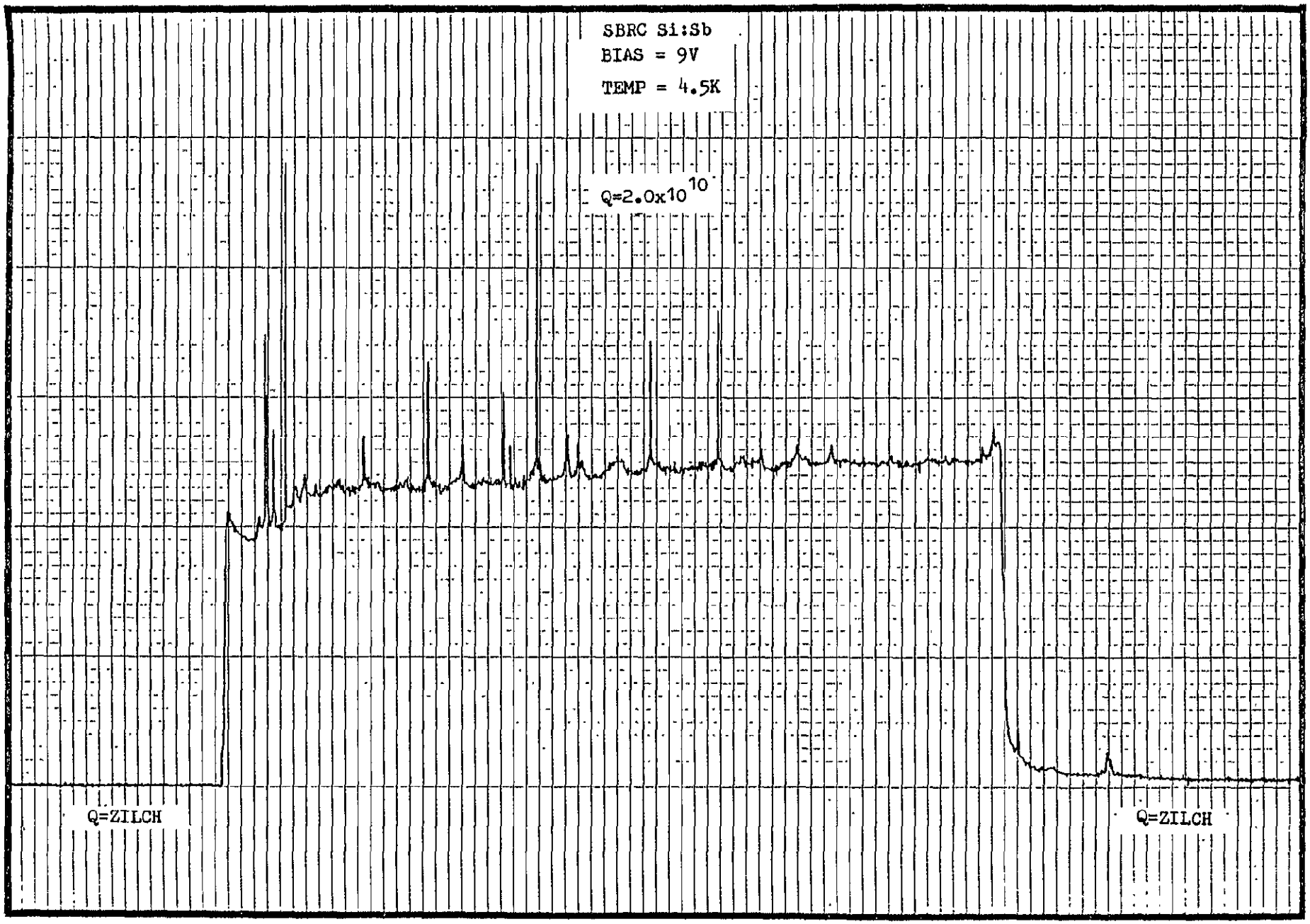

SBRC Si:Sb
BIAS = 9V
TEMP = 4.5K
Q=2.0x10^10
Q=ZILCH
Q=ZILCH
OUTPUT (20 mV/IN)
TIME (2 SEC/IN)

Figure 126

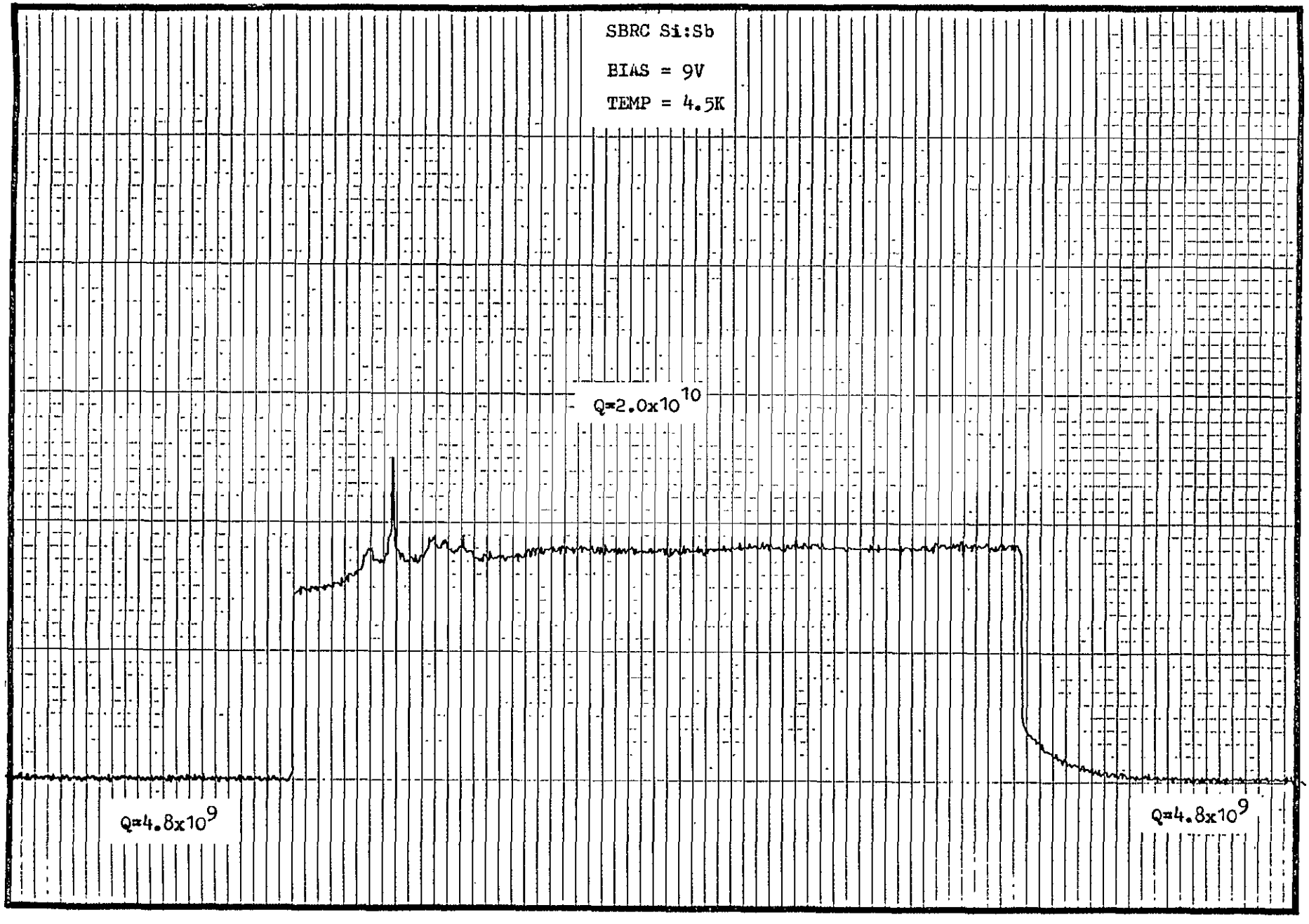

SBRC Si:Sb
BIAS = 9V
TEMP = 4.5K
Q=2.0x10^10
Q=4.8x10^9
Q=4.8x10^9
OUTPUT (20 mV/IN)
TIME (0.5 SEC/IN)

Figure 127

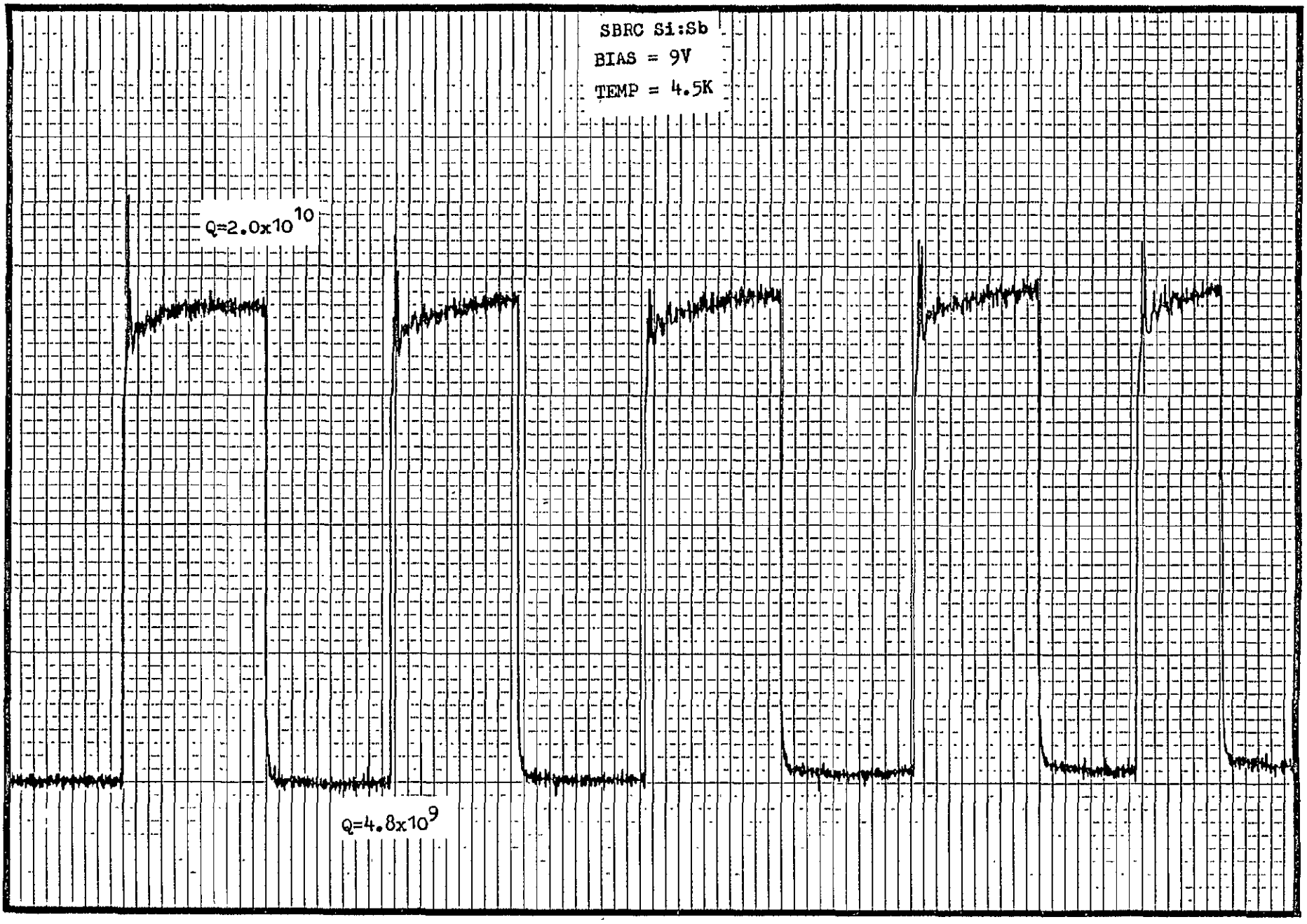

SBRC Si:Sb
BIAS = 9V
TEMP = 4.5K
Q=2.0x10^10
Q=4.8x10^9
OUTPUT (10 mV/IN)
TIME (10 SEC/IN)

Figure 128

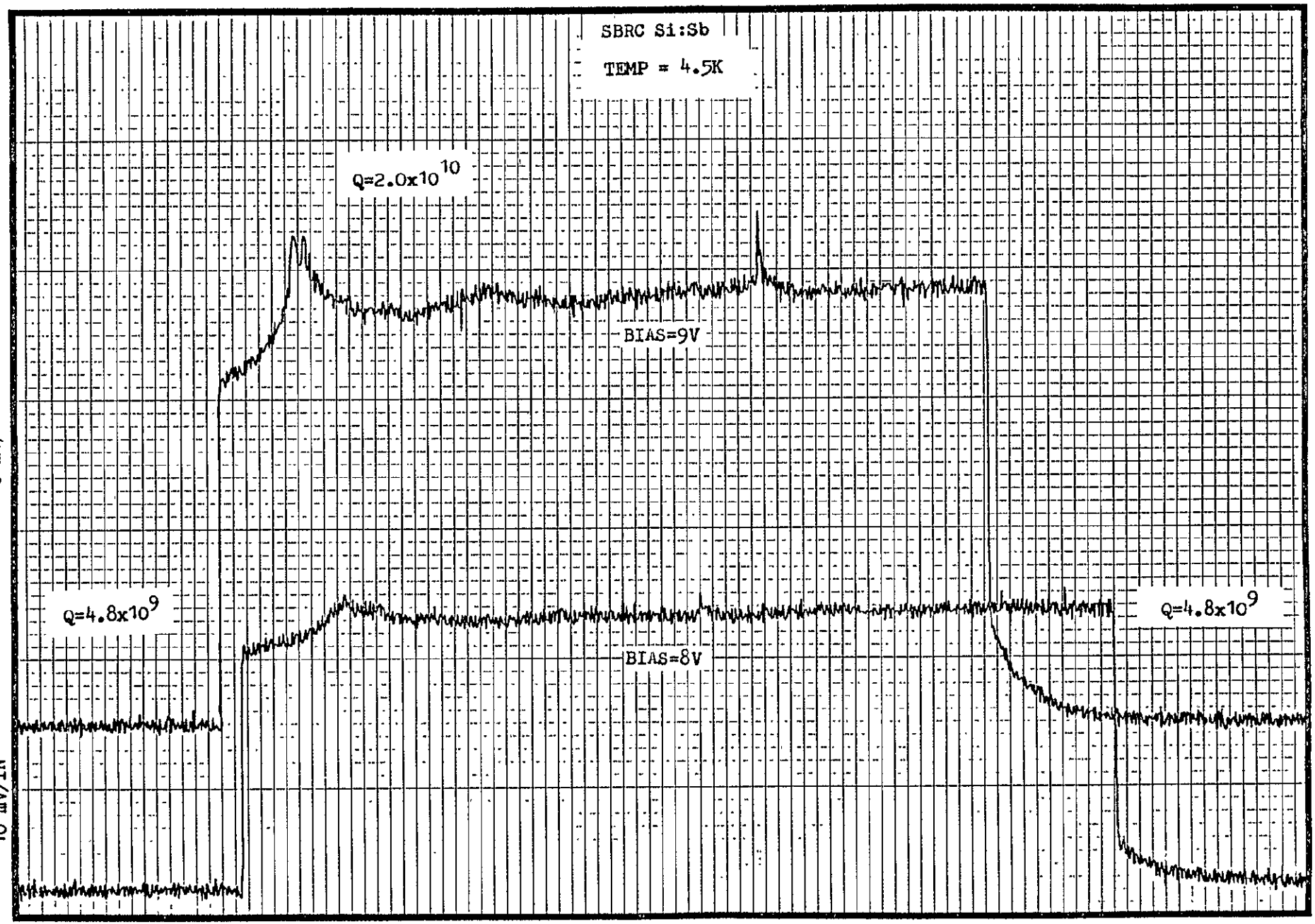

SBRC Si:Sb
TEMP = 4.5K
Q=2.0x10^10
BIAS=9V
Q=4.8x10^9
BIAS=8V
Q=4.8x10^9
OUTPUT VOLTAGE
10 mV/IN
10 mV/IN
TIME (0.5 SEC/IN)

Figure 129

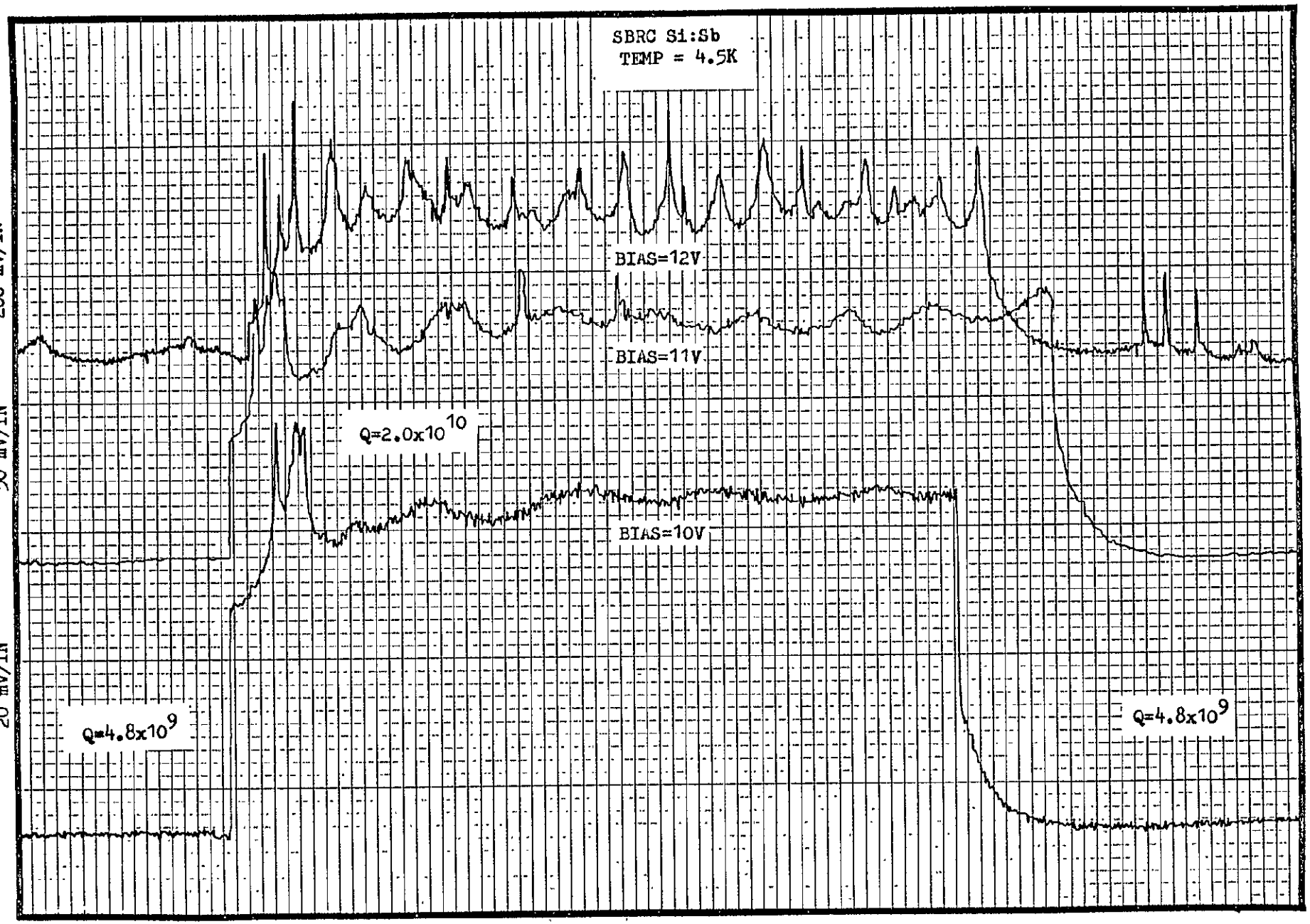

SBRC Si:Sb
TEMP = 4.5K
BIAS=12V
BIAS=11V
BIAS=10V
Q=2.0x10^10
Q=4.8x10^9
Q=4.8x10^9
OUTPUT VOLTAGE
200 mV/IN
50 mV/IN
20 mV/IN
TIME (0.5 SEC/IN)

Figure 130